Vol. 2 December 1956 No. 2

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CONTENTS

SARWAR, M.M., Studies on some trichostrongylids of ruminants from the Indo-Pakistan Sub-continent 145

HAFIZ, A., AKBAR, K. & SHARIFF, M., *Colletotrichum capsici* (Sydow) Butler & Bisby on *Piper betle* 216

BOIDIN, J., *Stereum ahmadi* nov. sp. (Basidiomycète : Théléphoracé) 217

STEWART, R. R., A bibliography of the flowering plants of West Pakistan and Kashmir 221

ISLAM, A., The postcranial skeleton of *Uromastix hardwickii* Gray 231

KHAN, SHAMS-UL-ISLAM, Residual effects of Colchicine 247

HAFIZ, A., KHAN, A. & AKBAR, K., *Meliola canarii* Syd. on *Bursera serrata* Wall. 252

FARIDI, M.A.F., A new species of *Nitella* from West Pakistan ... 254

KHAN, M.A., Studies on *Fimbriaria blumeana* Nees 256

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Studies on some trichostrongylids of ruminants from the Indo-Pakistan Sub-continent *

M. M. SARWAR

College of Animal Husbandry, Lahore.

Contents

I. Introduction 146

II. Classification of the Family Trichostrongylidae 148

a. Historical 150
b. Phylogenetic relationships of different groups in the Family ... 153
c. Morphological Characters considered in the classification ... 154
d. Personal observations 159

III. Genus **Ostertagia** s. lat. 159

a. History 159
b. Reconstruction of the genus 162

i. Genus *Ostertagia* s. str. 163

O. ostertagi (Stiles) 164
O. muraschkinzevi (Schulz & Kadenatzii) 165
O. mossi Dikmans 167

ii. Genus *Stadelmannia* n. g. 168

S. circumcincta (Stadelmann) 168
S. turkestanica (Petrow & Schachozewa) 170

* This work was done at the London School of Hygiene and Tropical Medicine and formed a part of the Thesis approved by the University of London for the degree of Ph. D.

S. trifurcata (Ransom) 171
S. pinnata (Daubney) 171

iii. Genus *Sjobergia* n. g. 173

S. lyrata (Sjoberg) 174
S. nemorhoedi (Schulz & Kadenatzii) 174

iv. Genus *Gruhneria* n. g. 175

G. bubalis n. sp, ... 176

v. Genus *Grosspiculagia* (Orloff) 177

G. trifida (Guille, Marotel & Panisset) 177

c. Geographical distribution of the species of *Ostertagia* s. lat. in West Pakistan 179

IV. **Genus Trichostrongylus** s. lat. 180

a. History 180

b. Reconstruction of the genus 181

i. Genus *Trichostrongylus* Looss 183

T. retortaeformis (Zeder) 184

ii. Genus *Gilesia* n. g. 184

G. colubriformis (Giles) 185
G. longispicularis (Gordon) 185
G. ovis n. sp. 186

iii. Genus *Buckleya* n. g. 186

B. vitrinus (Looss) 187

iv. Genus *Cobboldostrongylus* n. g. 187

C. axei (Cobbold) 188

v. Genus *Probostrongylus* n. g. 188

P. probolurus (Railliet) 189

P. hamatus (Daubney) 189

c. Geographical distribution of the species of *Trichostrongylus* s. lat. 189

V. References 191

I. INTRODUCTION

The present paper deals only with the genera *Ostertagia* and *Trichostrongylus* which are of economic importance and of which the former is generally regarded as particularly pathogenic. The reports on the genus *Ostertagia* from the Indo-Pakistan Sub-continent are meagre and tentative and perhaps the best piece of information relates to the species *Ostertagia*

ostertagi which is known to occur in the Punjab* and Mukteswar. Even this information is not without flaws : Bhalerao's (1942) identification of *O. ostertagi* is fallacious from his own account. The measurements of the specimens of *O. ostertagi* as quoted by Bhalerao (1942) and the shape of the dorsal ray as pointed out by him, correspond fully to those of *O. muraschkinzevi*. Similarly, the single specimen reported by Bhalerao (1932) as *O. occidentalis* was found, on re-examination, to correspond to *O. nemorhoedi*. The species *O. muraschkinzevi*, which was found by me to be one of the commonest helminths of goats at Mukteswar, has not so far been recorded from that locality. It is possible that this species was mistaken by Bhalerao (1932) for *O. circumcincta* which he recorded to be common in goats at Mukteswar. The incidence of *Ostertagia* spp., as judged from an examination of sheep and goats carried out by me in three Himalayan localities, viz., Murree, Kangra and Mukteswar, is very high and it is somewhat surprising that Pande (1942) who examined thirty goats at three places in the Himalayas (at heights 5000-7000 feet above sea level) could not find any species of *Ostertagia*. The reasons for such discrepancies are not very easy to explain but it is possible that in the past this group has remained comparatively obscure partly because the species present characters which do not always permit easy determination. An attempt has been made in this paper to offer a clarification of the subject against this background.

The information regarding the genus *Trichostrongylus* has not been satisfactory either. The species *T. colubriformis*, which was originally described from this Sub-continent, remained all along an unimportant parasite and Bhalerao (1935) described it as of rare occurrence. This species is now, however, known to be one of the commonest parasites of sheep and goats in the Sub-continent. Similarly *T. axei* which is as common as *T. colubriformis* in the hilly tracts, was recorded by Bhalerao only as late as 1942 from 'a few specimens' presented to him by a colleague. The other species, viz., *T. vitrinus* and *T. longispicularis* which have been reported in this communication, are recorded for the first time, although *T. vitrinus* occurs as a predominant trichostrongyle in sheep and goats in the North-Western region of West Pakistan.

This piece of work was carried out under the supervision of Prof. J.J.C. Buckley for whose invaluable help and encouragement I am deeply grateful. I am deeply indebted to Dr D. Swierstra of the Institute of Parasitology and Parasitic Diseases, Utrecht, Holland, for so very generously giving me

* This province was partitioned in 1947 between Pakistan and India. The Pakistani Punjab, comprising the Lahore, Rawalpindi, Multan and Bahawalpur Divisions has now been amalgamated with the great Province of West Pakistan. The Indian Punjab still bears that name.

a collection of *Ostertagia mossi* for study. I am grateful to Prof. M. Abdussalam for some very useful discussion and to Dr P. L. Le Roux for the interest he showed in my work. I must also thank Mr F. R. N. Pester for technical help.

II. CLASSIFICATION OF THE FAMILY TRICHOSTRONGYLIDAE LEIPER, 1922

a. HISTORICAL

The family Trichostrongylidae has had a very chequered history. Travassos (1921) divided this family into two subfamilies, namely Trichostrongylinae and Heligmosominae. Yorke & Maplestone (1921), on the other hand, divided it into four subfamilies, viz., Trichostrongylinae, Heligmosominae, Amidostominae and Strongylacanthinae. Baylis & Daubney (1926) raised the status of the Amidostominae to a full family, transferred the genus *Strongylacantha* to the family Ancylostomidae, and divided the rest of the family into two subfamilies, namely, Trichostrongylinae and Heligmosominae. Skrjabin & Orloff (1934) split up the family into Trichostrongylinae, Nematodiriinae, Mecistocirrinae and Heligmosominae. Neveu-Lemaire (1934) divided the Trichostrongyloidea into three families: Trichostrongylidae, Amidostomidae and Heligmosomidae. He split up the family Trichostrongylidae into two subfamilies, namely, Trichostrongylinae and Nematodiriinae.

Travassos (1937) divided the Trichostrongylidae into 12 subfamilies, namely, Trichostrongylinae, Ornithostrongylinae, Graphidiinae, Trichohelicinae, Amidostominae, Strongylacanthinae, Nematodiriinae, Mecistocirrinae, Heligmosominae, Viannaiinae, Oswaldoneminae and Ollulaninae. He divided the genera under the subfamily Trichostrongylinae into the following five groups :

Group A. *Cooperia* Ransom, 1907 ; *Paracooperia* Trav., 1935 ; *Cooperoides* Daubney, 1933 ; *Maciella* Trav., 1935 ; *Delicata* Trav., 1935 ; *Pithecostrongylus* Lubimov, 1930 ; *Molineus* Cameron, 1923.

Group B. *Trichostrongylus* Looss, 1905 ; *Libyostrongylus* Lane, 1923 ; *Hyostrongylus* Hall, 1921 ; *Ostertagia* Ransom, 1907 ; *Spiculopteragia* Orloff, 1933 ; *Marshallagia* Orloff, 1933; *Camelostrongylus* Orloff, 1933 ; *Travassosius* Khalil, 1922 ; *Pseudostertagia* Orloff, 1933.

Group C. *Obeliscoides* Graybill, 1924 ; *Leiperiatus* Sandground, 1929 ; *Travassostrongylus* Orloff, 1933 ; *Longistrongylus* Le Roux, 1931.

Uncertain genera : *Fontesia* Trav., 1928 ; *Nicollina* Baylis, 1930 ; *Pulchrostrongylus* Trav., 1935 ; *Dasypostrongylus* Trav., 1935.

Group D. *Herpetostrongylus* Baylis, 1931 ; *Amphibiophilus* Skrjabin, 1916 ; *Trichoskrjabinia* Trav., 1937 ; *Oswaldocruzia* Trav., 1917.

Uncertain genera : *Schulzia* Trav., 1937 ; *Moennigia* Trav., 1935 ; *Adolpholutzia* Trav., 1935.

Group E. *Hæmonchus* Cobb, 1898 ; *Ashworthius* Le Roux, 1930.

Travassos (1937) could not place the following genera with certainty in the preceding groups :

Filarinema Monnig, 1929; *Austrostrongylus* Chandler, 1924 ; *Boehmiella* Gebauer, 1932.

Skrjabin *et al* (1952) divided the family Trichostrongylidae into 15 subfamilies. It is not necessary to name all of them as the genera discussed in the present paper fall into 3 subfamilies, viz., Trichostrongylinae, Cooperinæ and Hæmonchiinæ only. A detailed classification of these subfamilies is given below.

Subfamily : Trichostrongylinae

Tribe : Filicapitea

Genus : *Filicapitis* Travassos, 1949

Tribe : Trichostrongylea

Genera : *Asymmetricostrongylus* Nagaty, 1932 ; *Trichostrongylus* Looss, 1905 ; *Libyostrongylus* Lane, 1923 ; *Paralibyostrongylus* Ortlepp, 1939.

Tribe : Longistrongylea

Genus : *Longistrongylus* Le Roux, 1929.

Tribe : Ostertagiea

Genera : *Ostertagia* Ransom, 1907 ; *Spiculopteragia* Orloff, 1933 ; *Marshallagia* Orloff, 1933 ; *Camelostrongylus* Orloff, 1933 ; *Rinadia* Grigorian, 1951 ; *Bigalkza* Monnig, 1931 ; *Parostertagia* Schwartz & Alicata, 1933 ; *Pseudostertagia* Orloff, 1933, *Obeliscoides* Graybill, 1924 ; *Travassosius* Khalil, 1922.

Subfamily : Cooperinae

Tribe : Cooperiea

Genera : *Cooperia* Ransom, 1907 ; *Cooperoides* Daubney, 1933,

Paracooperia Travassos, 1935.

Tribe : Hyostrongylea

Genera : *Macielia* Travassos, 1935 ; *Hyostrongylus* Hall, 1921 ; *Travassostrongylus* Orloff, 1933.

Tribe : Trichohelicea

Genus : *Trichohelix* Ortlepp, 1922.

Subfamily : Hæmonchiinae

Tribe : Hæmonchea

Genera : *Haemonchus* Cobb, 1898 ; *Ashworthius* Le Roux, 1930; *Leiperiatus* Sandground, 1930.

Tribe : Boehmiellea

Genus : *Boehmiella* Gebauer, 1932.

b. PHYLOGENETIC RELATIONSHIPS OF GROUPS IN THE FAMILY TRICHOSTRONGYLIDAE

The members of the family Trichostrongylidae are widely divergent in form, ranging from minute-sized species as in the genus *Trichostrongylus* to members having a strong resemblance in their head structures to ancylostomes, such as the genus *Strongylacantha.* A fairly good idea of the relationship of the groups in the family can be gained from the following characters :

1. *Anterior extremity* : The head generally shows three lips but it is difficult to make out any lips in genera, such as, *Trichostrongylus*, *Ostertagia* etc. In some genera, such as *Cooperia, Oswaldocruzia, Paracooperia* and *Ornithostrongylus,* the anterior extremity shows a thick cuticular covering. The cuticular covering at the head end takes the shape of a canopy in *Anopolostrongylus*, while in *Spinostrongylus*, the cuticular covering is helmet-shaped and has a circle of spines. Members of the genus *Molineus* show a rudimentary furrow on the ventral side of the extremity, homologous to that in the genus *Oesophagostomum.*

2. *Cervical papillae* : The cervical papillae are very prominent in certain genera, such as *Haemonchus* and *Ostertagia* but they are absent in others.

3. *Copulatory Bursa* : The bursa is of 2 types, viz., bilobed and trilobed. The bilobed bursa is characteristic of Nematodiriinae. The trilobed bursa is of many types as for example a small dorsal lobe intimate-

ly united with the lateral lobes and the development of dorsal and externo-dorsal rays being proportionate. This type of bursa is represented in a very large number of genera, such as *Trichostrongylus, Cooperia, Haemonchus, Oswaldocruzia* etc. In some genera, such as, *Fuellebornema* and *Heligmostrongylus*, the dorsal ray exceeds the outer rays in development and the dorsal lobe is larger than the lateral lobes. In *Heligmonina* the development of the bursa is asymmetrical, a portion of the dorsal ray being more developed. In *Oswaldonema* the asymmetry is manifest in greater development in the size of the rays of one portion while in *Lutznema* the cloaca is dislocated from the middle line.

4. *Female genital aperture* : The aperture is generally situated behind the middle of the body and has the form of a rectilinear slit or a transverse arc, and may or may not be covered by a backwardly directed cuticular flap. In some genera, such as, *Mecistocirrus* and *Trichohelix* the vulva is located just above the anus and the uteri are parallel.

5. *Markings on the lateral lobes of the bursa* : Only a passing notice appears to have been taken, by previous workers, of the markings on the inner side of the lateral lobes of the bursa and from the meagre information available in literature on the subject it is clearly brought out that the patterns of bursal markings correspond a good deal to the taxonomic classification based on other morphological characters as indicated below :

In the genus *Molineus* (subfamily Molineinae) the presence of small spines on the inner face of the bursa has been indicated in the majority of the species. Cameron (1923) described small spines on the central portion of the lateral lobes of the bursa in *Molineus felineus*. Similar structures were indicated by Petrow (1928) in *Molineus patens* and by Cameron (1927) in *Molineus genettae*.

In the genus *Obeliscoides* (subfamily Ostertagiinae subf. n.) the internal surface of the lateral lobes in both *O. leporis* and *O. cuniculi* has been described as showing small circular bosses in a fine mosaic design in the central portion and radial striations at their margins. Chandler (1924) figured and described the character in *O. cuniculi* as follows : "The entire ventral surface of the bursa except a fluted margin about 40μ in width is thickly covered with dew-drop like bosses".

The lateral lobes of the bursa have been described in almost all the species of the genus *Nematodirus* (subfamily Nematodiriinae) as showing cuticular bosses of essentially the same pattern. The bosses have been figured by Rayewskaja (1931) in *N. tarandi* (*vide* Travassos, 1937), *N. as-*

pinosus and *N. filicollis*, by Chandler (1924) in *N. leporis* and by Boughton (1932), Dikmans (1937) and Durbin (1951), respectively, in *N. triangularis*, *N. aspinosus* and *N. rufaevastitatis*.

In the subfamily Amidostominae this character was described and figured by Travassos (1937) for *Amidostomum anseris* as showing reticular striations in the central portion and radial at the margins. Wetzel (1931) described "strong reticulate striations" on the lateral lobes of the bursa in *Epomidiostomum uncinatum* (Lundahl, 1848). Travassos (1937) described the striations on the lateral lobes in *E. vogelsangi* as arborescent, reticular and changing to radial at the margins.

In the genus *Nochtia* (subfamily Nochtiinae) Travassos (1937) described the presence of cuticular bosses in the central portion of the lateral lobes of the bursa. Cameron (1931) described the presence of bosses in the central area and radial striations at the margins of the lateral lobes in *Nicollina sarcophili*, also a member of the same subfamily.

In the subfamily Anoplostrongylinae, the markings on the lateral lobes of the bursa have been described for the genera *Pithecostrongylus*, *Molinostrongylus* and *Nycteridostrongylus*. Lubimov (1930) described and figured small triangular spines on the internal surface of the lateral lobes of *Pithecostrongylus alatus*. The lateral lobes of bursa in the genus *Molinostrongylus* have been described as showing numerous cuticular spines. Skarbilovitch (1934) described the character in *M. skrjabini* as follows "La partie intèrieure des lobes latéraux est couverte d'épines ; la zone périphérique de la bourse et la partie située entre les côtes dorsales externes sont privées de ces épines". Ortlepp (1932) described spike like chitinous processes in *M. alatus* on the ventral surface of lateral lobes of the bursa. Baylis (1930) observed cuticular spines on the major part of the bursa in *M. heydoni*. Ortlepp (1932) described the presence of cuticular spines on the inner surface of the bursa in *M. ornatus* (Monnig, 1927). The presence of numerous small cuticular spines on the lateral lobes has been noted in *Nycteridostrongylus* by Baylis (1930).

Travassos (1937) described the lateral lobes of the bursa in the genus *Strongylacantha* (subfamily Strongylacanthinae) as finely granular.

In the genus *Ierestrongylus* (subfamily Ollulaninae) small processes on the inner surface of lateral lobes of the bursa were described by Travassos (1937). Cameron (1935) described the bursa in *I. filiformis* as "scalloped" at the edges and showing numerous small projections on its inner surface.

c. MORPHOLOGICAL CHARACTERS EMPLOYED IN THE CLASSIFICATION OF THE FAMILY TRICHOSTRONGYLIDAE

The diversity in the morphology of the members of the family Trichostrongylidae has already been discussed under the heading of phylogenetic relationship. The criteria used for the classification of the family largely relate to the following characters :

1. *Form of head end.* For example, Strongylacanthinae in which the head end is furnished with teeth.

2. *Location of female genital aperture.* For example, Mecistocirrinæ in which the genital aperture is located adjacent to the anal opening.

3. *Form of the copulatory bursa.* For example, Nematodirinæ in which the bursa is bilobed ; Trichostrongylinae, in which the bursa is composed of two large lateral and a small median lobe ; Heligmosominae, in which the bursa is either asymmetrical or the dorsal lobe is more developed than the lateral lobes.

Neveu Lemaire (1934) classified Trichostrongyloidea on the following characters :

1. Female genitalia paired ;

   a. Buccal capsule absent ... ... Trichostrongylidae
   b. Buccal capsule rudimentary ... ... Amidostomidae

2. Female genitalia unpaired ... ... Heligmosomidae

Travassos (1937) laid stress on the form and composition of the copulatory bursa particularly the shape of the dorsal ray.

Skrjabin *et al* (1952) created a number of subfamilies and laid stress on the shape of anterior extremity. The subfamilies which he particularly based on this character are Cooperinae and Haemonchiinae.

For a differentiation of genera, such as *Ostertagia* and *Cooperia*, Ransom (1907) took into consideration the form of the ventral rays as the only important character of the bursa. Skarbilovitch (1934) laid emphasis on the structure of dorsal ray for generic differentiation. Quoting Skarbilovitch (1934) "Lé étude détaillée de la structure de toutes espéces classées actuellement dans le genre *Anoplostrongylus* me donne lieu de conclure que ce genre contient des représentants de deux genres indépendants. En particulier par la structure des spicules et la côte dorsale (caractéres d' importance générique), *A. paradoxus* represente l espéce type du genere *Anoplostrongylus* et différe notablement des autres représentants de ce genre".

d. PERSONAL OBSERVATIONS ON THE MORPHOLOGICAL CHARACTERS OF SIGNIFICANCE IN THE CLASSIFICATION OF TRICHOSTRONGYLIDAE

A large number of genera characterized by the bursa having two large lateral and a small median lobe continued to be included in the subfamily Trichostrongylinae, until Skrjabin *et al* (1952) divided the subfamily by creating a number of subfamilies, such as Hæmonchiinæ, Cooperinae, Oswaldocruziinae, Filarinematinae and Nochtiinae. The long standing stalemate in the progress towards this division may be largely ascribed to the indistinct head end structures in the members of the subfamily. The head end structures have, in several cases, created confusion, as for example *Hyostrongylus rubidus* (Stiles & Hassal, 1892) was placed by Travassos (1921) in the genus *Ostertagia* but a new genus *Hyostrongylus* was created for the species by Hall (1921). Skrjabin *et al* (1952) placed the genus *Hyostrongylus* under the subfamily Cooperinae, thus suggesting its relationship as closer to the genus *Cooperia* than to the genus *Ostertagia*. While giving due importance to the character of the head end, too much reliance cannot be placed on the head end due to the obscurity of its structures in this group. The summation of the position on this point by Chitwood & Chitwood (1950) seems to be very clear and is quoted here *in extenso*. "The structure of the stoma has generally been used as a taxonomic character since the beginning of nematology. Its wide use for the classification of groups of all ranks makes a thorough consideration of its evolution necessary. That its morphology has great value can scarcely be doubted by any worker in the field but the weight that may be given to its gross form seems dubious. Since the method of feeding and character of the food itself is limited by the stoma and its armature, this organ is probably more directly influenced by environment than any other. A radical change of feeding habits of closely related forms would require change in stomatal morphology if forms are to survive. Likewise, it is not at all inconceivable that quite unrelated nemas coming to feed in the same manner might eventually become grossly similar as regards stomatal morphology. For the above reasons one must consider stomatal morphology very closely".

The character of the copulatory bursa has been used by many workers for generic differentiation and a study of the bursa in the members of the family Trichostrongylidae shows that the variations for the generic and family groupings are, respectively, best manifest in the dorsal ray and ventral rays organization. The patterns of markings on the lateral lobes of bursa which had so far only received a passing notice, were, on study, found to offer an important criterion for the classification. In the following discussion only two criteria, viz., the organization of ventral rays and mar-

kings on the lateral lobes of bursa have been considered.

1. *Organization of ventral rays.* In figures 3, 6, 7, 9, and 11-14 are reproduced drawings showing the shapes and arrangements of ventral rays in the genera which had been included in the subfamily Trichostrongylinae by Travassos (1937). The figures were reproduced by transcription with the help of camera lucida.

The sources from which the figures have been derived are as follows :

Details of the drawings	*Sources*
Figures 3, 6, 7, (except *M. marshalli*), 9 (except *H. contortus*),) 11 (except species of *Trichostrongylus*) and 12-14.	Travassos, 1937
M. marshalli	original
T. tenuis, T. capricola, T. vitrinus	Nagaty, 1932
Haemonchus contortus	Le Roux, 1929

A consideration of the drawings reproduced reveals the fact that the genera represented in the figures could be arranged in groups on the basis of shapes and arrangement of ventral rays. The groups constituted on the basis of this character are found, on examination, to correspond to the groups otherwise formed on the basis of characters, such as, form of the head end, presence or absence of cervical papillae and the location of the female genital opening. The groups that have been constituted on the basis of the shape and organization of ventral rays are detailed as follows :

Group. I. The group is formed by the genera *Cooperia, Paracooperia* and *Cooperoides*. The ventral rays in these genera appear to stand as follows :

The tip of the ventro-ventral widely separated from the ventro-lateral, the proximal half of ventro-lateral thick and diverging from the ventro-ventral and distal half considerably attenuated and turned towards the ventro-ventral, ventro-ventral thin and its tip turned forward.

The genera constituting the *Cooperia* group show important differences in shape of their dorsal rays.

Group II. The group is constituted by the genera *Ostertagia* sensu lato, *Marshallagia, Hyostrongylus, Camelostrongylus, Bigalkea, Spiculopter-*

agia, Obeliscoides, Rinadia, Skrjabinagia and *Longistrongylus*. The shape and arrangement of ventral rays in these genera may be defined as follows :

Ventral rays contiguous in their proximal portions, diverging in their middle, converging in their distal thirds and thus forming a sub-triangular area between them.

The genera constituting the *Ostertagia* group show important differences in the shape of their dorsal rays.

Group III. The group is formed by the genera *Haemonchus, Ashworthius* and *Leiperiatus*. The shape and arrangement of ventral rays in these genera may be defined as follows :

Ventral rays gradually diverging from each other from their origin and directed in the same direction in their course.

The genera constituting the *Haemonchus* group show important differences in the shape of their dorsal rays.

2. *Markings on the lateral lobes of bursa.* In figures 2, 4, 5, 8 and 10 are reproduced drawings showing patterns of markings on the lateral lobes of bursa. These drawings are based on material originating as follows :

Material	*Origin*
Cooperia pectinata, Ostertagia ostertagi, Ostertagia lyrata, Ostertagia muraschkinzevi, Ostertagia occidentalis, Ostertagia nemorhoedi, Ostertagia circumcincta, Ostertagia pinnata, Camelostrongylus mentulata. Marshallagia marshalli, Trichostrongylus axei.	West Pakistan
Longistrongylus meyeri, Graphidium strigosum, Cooperoides sp., *Molineus felineus.*	London School of Hygiene & Tropical Medicine.
Ostertagia mossi, Spiculopteragia asymetrica.	Institute of Parasitology & Parasitic Diseases, Utrecht, Holland.

The cuticular markings on the lateral lobes could be satisfactorily studied on clearing in lactophenol and it was found that the markings had been distorted in specimens which had been fixed in formalin (fig. 1).

The genera are grouped as follows on the basis of cuticular markings on the bursa. The markings in figure 10 are reproduced only for comparison with the first three groups :

Group. I. The group is constituted by the genera *Cooperia, Paracooperia* and *Cooperoides*. The cuticular markings in species of these genera consist of minute bosses in the centre and striations at the margins.

Group II. The group is constituted by the genera *Ostertagia s. lat. Marshallagia, Camelostrongylus, Rinadia, Bigalkea, Longistrongylus, Skrjabinagia, Hyostrongylus* and *Spiculopteragia*. The cuticular markings on the bursal membrane consist of large plaques resembling those on crocodile skin in the centre and longitudinal striations at the periphery. The plaques are large in the proximal portion of the lateral lobe gradually diminishing in size distally.

Group III. The genera included in the group are as follows: *Haemonchus, Ashworthius* and *Leiperiatus*. The bursal markings in *Haemonchus contortus* were found to consist of a transversely running row of superimposed bosses in the centre of the lobe and longitudinal striations formed by the fusion of small bosses running from the centre of the lobe towards the periphery. The two portions of the markings show a distinct gap between them.

Le Roux (1930) did not give a description of the markings on the bursal membrane of the lateral lobes in *Ashworthius* but remarked that the markings on the bursa of *Ashworthius* were of the same type as in *Haemonchus*. Travassos (1937) described the markings in *Leiperiatus* as constituting a delicate mosaic design with the margins radially striated.

The following changes are suggested in the classification proposed by Skrjabin *et al* (1952) in consideration of the characters of the bursa described above.

Group I. Subfamily Cooperinae.

Only the genera *Cooperia, Paracooperia* and *Cooperoides* (grouped by Skrjabin *et al* (1952) under the tribe Cooperiea) should be included in the subfamily and the rest of the genera, namely, *Macielia, Hyostrongylus Travassostrongylus,* and *Trichohelix* should be removed from the subfamily and placed elsewhere. For example, *Trichohelix* should remain in the subfamily Trichohelicinae Travassos, 1937. Again, *Hyostrongylus rubidus* was found, on examination, to be more closely related to the *Ostertagia* group both in the organization of the ventral rays and the markings on the lateral lobes of bursa.

Group II. Subfamily Trichostrongylinae.

The subfamily has been divided into four tribes, namely, Filicapitea, Trichostrongylea, Longistrongylea and Ostertagiea. It is suggested that

Longistrongylea and Ostertagiea, which have common characters widely differing from Trichostrongylea and Filicapitea, may be placed under a new subfamily created for their reception under the name of Ostertagiinae. Skrjabin *et al* (1952) included the genus *Pseudostertagia* in the tribe Ostertagiea. Travassos (1937) remarked that *Pseudostertagia* bore a greater resemblance to *Trichostrongylus* than to *Ostertagia* and on the basis of the foregoing suggested characters the author agrees with the opinion advanced by Travassos (1937). As already suggested *Hyostrongylus rubidus* which had originally been described under the genus *Ostertagia* but has been grouped along with *Cooperia* by skrjabin *et al* (1952), belongs to the sufamily Ostertagiinae on grounds of markings on the bursa and organization of the ventral rays.

Group III. Subfamily Haemonchiinae.

The subfamily was divided by Skrjabin *et al* (1952) into two tribes, namely, Haemonchea and Boehmiellea and included the following genera under them.

(*a*) Haemonchea : *Haemonchus*, *Ashworthius* and *Leiperiatus*.

(*b*) Boehmiellea : *Boehmiella*.

The author arrived at the conclusions on the grouping together of *Haemonchus*, *Ashworthius* and *Leiperiatus* independently of Skrjabin *et al* (1952). In *Boehmiella* the organization of the ventral rays and the structure of the head end conform to the subfamily Graphidiinae and not Haemonchiinae.

The genera included in the subfamilies Haemonchiinae and Ostertagiinae together offer such distinctive characters as to make their grouping along with other subfamilies, under one family, as unsatisfactory. The presence of large cervical papillae, the gradually tapering anterior extremity and the bursal markings characterise the two subfamilies and distinguish them from the other groups. A new family Ostertagiidae is proposed for the reception of the subfamilies Ostertagiinae and Haemonchiinae. A definition of the family Ostertagiidae is as follows :

Ostertagiidae n. fam.

Trichostrongyloidea : Body filiform and more or less dark brown in colour ; anterior extremity tapering gradually anteriorly ; head end furnished with fine anteriorly directed papillae ; cervical papillae very prominent and triangular in shape ; buccal capsule rudimentary ; bursa comprising two large lateral and a small median lobe ; bursal membrane of the bursal lobes

showing closely set plaques in the central portion and longitudinal striations near the periphery ; vulva situated beind the middle of the body ; eggs segmenting when laid.

Parasites of herbivores.

A definition of the subfamily Ostertagiinae is as follows :

Ostertagiinae n. subf.

Ostertagiidae : Ventral rays subequal, medium sized, united in the proximal third, diverging in the middle third and again converging in the distal third ; buccal capsule rudimentary and unarmed ; membrane of the lateral lobes showing plaques as on crocodile skin in its proximal portion and longitudinal striations at its periphery ; accessory bursal membrane prominent ; tail of female showing transverse striations near its tip ; vulva covered by a hyaline flap.

TYPE-GENUS : *Ostertagia* Ransom, 1907.

III. GENUS *OSTERTAGIA* RANSOM, 1907

a. HISTORY

Ransom (1907) created the genus *Ostertagia* and included the following species under it : *O. circumcincta, O. ostertagi, O. trifurcata, O. marshalli and O. occidentalis*. The genus was created on the basis of the following characters :

"Important characters of this genus are the presence of cervical and prebursal papillae ; the two ventral rays of the bursa close together, with their tips in relation to a more or less conspicuous indentation of the bursa; the presence of an accessory bursal membrane attached to the dorsal end of the body near the dorsal side, inside the bursa ; accessory piece of the spicules present or absent, inconspicuous, if present".

Ransom (1911) defined the genus as follows :

Trichostrongylidae : Head less than 25μ in diameter, with six indistinct lips or papillae surrounding the mouth. Mouth cavity small. Cervical papillae present. Cuticle marked with 25 to 35 longitudinal ridges appearing as simple lines, except under high magnification when they sometimes show a finely beaded appearance. Cuticle of head may be slightly dilated, forming a narrow collar or annulus. Bursa with two lateral lobes united by a smaller median lobe. Each lateral lobe supplied with six supporting rays. The two ventral rays are close together and their tips are in relation with a more or less conspicuous indentation of the bursa. The dorsal ray

separates into two main branches which may divide distally into two short branches or give off one or two short side branches internally or externally. Attached to the posterior end of the body of the male toward the dorsal side and inside the bursa there is an accessory bursal membrane with a free posterior edge supported by two slender diverging rays. The spicules are short (less than 1mm. in length), similar in size and shape and are divided lengthwise in the distal portion into two or three processes. An accessory piece or gubernaculum may be present or absent. When present it is inconspicuous, colorless and drawn out into a slender process posteriorly. Prebursal papillae present. Vulva less than one-fifth the length of the body from the posterior end, naked or covered by a thin, backward projecting, cuticular flap. Ovejectors well developed. Eggs oval, with thin shells.

TYPE SPECIES : *Ostertagia ostertagi* (Stiles, 1892).

Dikmans (1931) amended the definition of the genus and divided the 23 species then known under the genus, into the following 4 groups :

Group A. Spicules undivided : *bullosa, asymetrica, houdemeri.*

Group B. Spicules bifurcated : *mentulata, turkestanica, khalili, circumcincta.*

Group C. Spicules trifurcated : *occidentalis, skrjabini, lyrata, mossi, marshalli, odocoilei, ostertagi, appendiculata, bisonis.*

Group D. Termination of spicule not determined : *trifurcata, brigantica, ransomi, callis, delicata.*

Orloff (1933) split the genus into *Ostertagia, Camelostrongylus* and *Travassostrongylus* with a single species under each of the two latter genera. He, at the same time, subdivided the genus *Ostertagia* into 5 subgenera, namely, *Ostertagia, Grosspiculagia, Spiculopteragia, Marshallagia* and *Pseudostertagia* and offered the following differential diagnosis for the subgenera :

I. Spicules split at the distal extremity ; cervical papillae and accessory membrane of the bursa distinctly stand out.

A. An accessory piece present.

1. Spicules divided at their posterior extremity into branched end ; dorsal ray medium; lateral lobes of the bursa well delimited or defined by a small median lobe. ... ... Subgenus *Ostertagia.*

The species included in the subgenus are : *appendiculata, arctica, circumcincta, dahurica, ransomi, trifurcata, odocoilei*

ostertagi, orloffi, delicata, gruhneri, harrisi, khalili, mossi.

2. Spicules divided at their posterior extremity in branches out of which two are very thick ; dorsal ray long ; lateral lobes feebly or not at all delimited or defined by a long median lobe. ..... Subgenus *Grosspiculagia.*

The species included in the subgenus are : *lyrata, occidentalis.*

B. Accessory piece absent.

1. Spicules provided at their posterior extremities with fan form membranes ; dorsal ray short and thick ; lateral lobes of the bursa distinctly divided by an insignificant median lobe....Subgenus *Spiculopteragia.*

The following species are included in the subgenus : *spiculoptera, asymetrica, houdemeri, schulzi, cervi.*

2. Spicules without fan shaped membrane ; dorsal ray long thin and slender ; lateral lobes feebly or not at all delimited by a long median lobe. ... ... Subgenus *Marshallagia.*

The only species in the subgenus is *marshalli.*

II. Spicules undivided at the posterior extremity ; cervical papillae absent ; supplementary membrane of the bursa poorly developed. ... ... Subgenus *Pseudostertagia.*

This subgenus is represented by a single species, *bullosa.*

Travassos (1937) raised the subgenera *Spiculopteragia, Marshallagia* and *Pseudostertagia* to the status of full genera and suppressed the subgenus *Grosspiculagia.* Travassos (1937), at the same time, created a new genus (*Delicata*) to accommodate the species, *appendiculata, delicata, khalili* and *ransomi.*

Schulz & kadenatzii (1950) proposed the subgenus *Costarcuata* for the species *ostertagia muraschkinzevi.* skrjabin *et al* (1952) upheld this subgenus as well as the subgenus *Grosspiculagia* Orloff 1933.

Kassimov (1942) proposed the subgenus *Skrjabinagia* with the species *popovi* as its type and transferred *Ostertagia bisonis* and *Ostertagia odocoilei* to it. The three species included in the subgenus have the common characteristics of an accessory piece being absent. The drawing of male

tail of *Ostertagia (S.) popovi* (Skrjabin, 1952, page 789) by Ksssimov (1942) is not sufficiently clear and illustrative and does not permit an adequate study of the branching of the spicules and the material need re-examination. Altaev (1952) quoted by Altaev (1953) raised the subgenus *Skrjabinagia* to the status of a full genus and added the species *dagestanica* to it. Altaev (1953), at the same time, transferred the species *Ostertagia (O.) tundra* Gnedina and Antipin, 1934, *Ostertagia (Marshallagia) butschnewi* Rudakoff, 1937, *Spiculopteragia houdemeri* (Schwartz, 1927), *Spiculopteragia cervi* (Cameron, 1931) to the genus, the only reason stated by Altaev (1953) for this arrangement being the absence of an accessory piece in these species. Altaev (1953) stated that the presence or absence of an accessory piece was a convenient character for classification, but, there does not appear to lie enough justification for this suggestion, as the species that have been grouped together on the basis of convenience are otherwise divergent in important details.

Grigorian (1951) created the genus *Rinadia* to accommodate the species *schulzi* which he recorded from *Capreolus capreolus* from U.S.S.R. The creation of the genus *Rinadia* by Grigorian is ascribable evidently to faulty interpretation of structures by Grigorian. What had been described by him as the dorsal ray of the bursa, in reality, represents the accessory bursal rays common to all the ostertagiines. The structures of the male tail of *Ostertagia nemorhoedi* Schulz & Kadenatzii (1950) show such striking resemblance to those of *R. schulzi* that it makes it difficult to accept Grigorian's statement that the accessory piece in the species *R. schulzi* is rudimentary.

b. RECONSTRUCTION OF THE GENUS OSTERTAGIA

The genus *Ostertagia,* as at present constituted, is composed of varied forms and no precise definition of the genus is available in literature. The differences between groups of members under the genus are so marked that the present arrangement of their being grouped under one genus is altogether unsatisfactory. The differences manifested in the arrangement of the lateral rays, the shape of the dorsal ray, the shape of the distal portions of the spicules and the shape of the cloaca, in *Ostertagia ostertagi* and *ostertagia muraschkinzevi* on one hand and *Ostertagia circumcincta* and *Ostertagia pinnata* on the other, have been illustrated (fig : 15) A number of other members of the genus fall in either of the two groups and these differences, consistently present in particular sets, are wide enough to justify the separation of the groups in two genera. Similar evidence can be advanced to show that the subgenus *Grosspiculagia,* is composite. The groups falling

under the subgenus *Grosspiculagia*, headed by *occidentalis* on one hand and *lyrata* on the other, show the irreconcilable difference in the externo-dorsal ray being the thinnest of all the rays in the species *occidentalis* and thickest in *lyrata*. Yet another new genus is proposed for the species *O. gruhneri* Skrjabin, 1929 and a new species frem buffaloes in Pakistan on grounds of absence of gubernaculum and the dorsal ray being rudimentary.

A differential key for the genera proposed is as follows :

1. Bursa showing a medium sized dorsal lobe or dorsal ray.

A. Postero-and medio-lateral rays close together and divergent from the antero-lateral ... ... *Ostertagia*

B. Medio-and antero-lateral rays close together and divergent from the postero-lateral ... ... *Stadelmannia* n.g.

2. Bursa showing a long dorsal lobe or dorsal ray.

A. Externo-dorsal thinnest of all the lateral rays... ... *Grosspiculagia*.

B. Externo-dorsal thickest of all the rays... ... ... *Sjobergia* n.g.

3. Bursa showing a much reduced dorsal lobe. Postero-lateral ray longer than any other ray and divergent from the other laterals. ... ... *Gruhneria* n.g.

The material for the following species, on which the study of the genus is based, had been collected in Indo-Pakistan :

O. ostertagi, O. muraschkinzevi, O. circumcincta, O. pinnata, O. trifurcata, O. turkestanica, O. occidentalis, O. lyrata, O. nemorhoedi.

O. mossi was obtained from the Institute of Uarasitology and Uarasitic Uiseases Utrecht, Holland :

The specimens of *O. circumcincta, O. pinnata* and *O. trifurcata* were collected from the London Slaughter House.

1. **Ostertagia** Ransom, 1907

The genus may now be defined as follows :

Ostertagiinae : Male. Bursa comprising two large lateral and a distinctly marked small dorsal lobe ; ventral rays unequal ; ventro-lateral ray slightly thicker than the other paired rays of nearly equal thickness ; postero-and medio-laterals close together and divergent from the antero-lateral and their tips reaching the bursal margin ; dorsal ray medium in

size and bifurcating posterior to its middle and its branches showing bifid terminations. Spicules split in their distal fourth into three branches, the main thick shaft with a truncated end and two barbed slender processes. Gubernaculum showing a thick proximal and a slender distal portion. Genital opening bounded by two chitinous protuberances.

Female : Vulva covered by a backwardly directed hyaline striated cuticular flap ; tail tapering gradually and ending in a slender rounded tip.

Parasites of ruminants.

TYPE SPECIES : *Ostertagia ostertagi* (Stiles, 1892) Ransom, 1907.

The other species conforming to the definition of the above genus are as follows :

O. muraschkinzevi, O. mossi, O. orloffi, O. antipini, O. petrowi and *O. tatiani.*

Ostertagia ostertagi (Stiles, 1892) Ransom, 1907

(Figs. 16 & 17)

The parasite is of cosmopolitan occurrence and is found to occur in cattle and goats in the hilly areas of the Punjab. The author found the parasite also in a collection, from a goat from Kasauli, which had been deposited by Clayton Lane in the British Museum (Natural History). The measurements of the material, in millimeters, are as follows :

MALE : Body length 6.5-8 ; maximum width in front of bursa of 0.16-0.17 ; nerve ring and cervical papillae situated, respectively, at a distance of 0.22-0.26 and 0.35-0.39 from the anterior extremity ; length of oesophagus 0.71-0.73 and its maximum width, near the posterior end of 0.06 ; spicules dark yellowish brown in colour and measuring 0.23-0.27 long ; gubernaculum about 0.09 long.

The bursa is comparatively small and is composed of two large lateral and a small median lobe. The body of the male is seen projecting backwards between the wings of the bursa and the genital opening is marked by two chitinous somewhat rounded pieces separated by a shallow median groove. The dorsal ray is 0.05-0.06 long and bifurcates at a distance of 0.035-0.045 from its root. Each of the branches has a bidigitate termination and in some examples the inner digit is further bidigitate.

The spicules are split, at a distance of 0.062-0.065 from the distal end, into a thick middle branch and two barbed slender processes arising from the inner side of the spicule and forming the dorsal and ventral bran-

ches. According to Ransom (1911) the body of the spicule is truncated at its distal end forming the thick middle branch while Baylis (1936) defined the termination as ending in a knob. A close study of the spicules revealed the distal end as truncated and bent like a shepherd's hook.

FEMALE : Body length 8-10 ; vulva covered by a backwardly directed cuticular striated flap and situated at a distance of 1.5 from the tail end ; tail tapering gradually to end in a slender rounded tip bearing about half a dozen transverse striations.

HOST : *Bos indicus, Capra hircus.*

LOCATION. Pyloric portion of abomasum.

LOCALITY. 1. Sialkot-West Pakistan. The animal had most probably been raised in the neighbouring Jammu hills.

2. Choa Saidan Shah-West Pakistan. The tract has an average height of 2500 feet above sea level.

3. Kasauli-East Punjab. A locality in outer Himalayas at a height of about 6000 feet above sea level.

Ostertagia muraschkinzevi Schulz & Kadenatzii, 1950

(Fig. 18)

The species *O. muraschkinzevi* was originally described by Schulz and Kadenatzii (1950) from *Nemorhoedus goral* in Russia and the information on the species has so far remained confined to its original record. It is somewhat extraordinary to find that this species which is known from a solitary record of occurrence in Russia is perhaps the commonest helminth of sheep and goats in Himalayas and it is possible that a similar situation may exist in some other parts of the World. The author examined not less than twenty sheep in the slaughter houses at Murree (a locality in outer Himalayas) and all the animals were found to harbour these parasites in large numbers. The species was also found to occur at lower altitudes, such as, Choa Saidan Shah. A possible explanation for the obscurity of the species appears to lie in the fact that the parasite may have, in literature, been confused with *O. circumcincta* due possibly to a marked similarity in gubernacula of the two species. There are strong grounds for believing that Daubney's *circumcincta* which Daubney (1933) recorded from Kenya and Koffman's *circumcincta* which Koffman (1942) recorded from Skandinavia, belong to this species. The spicules of *circumcincta* in Daubney's drawing are unlike those of *circumcincta* of Ransom (1911), Travassos

(1921), Gebauer (1932) and Saquenet (1946) and, instead, have a striking resemblance with those of *O. muraschkinzevi*. Daubney's description that "large membranous expansions support the branches of the spicules which measure 0.28-0.32 mm. long, lends further support to the conclusion that the species was confused with *circumcincta*. So far as *circumcincta* of Koffman (1942) is concerned, the photograph of spicules by Koffman leaves little doubt that these belong to the species *O. muraschkinzevi* and not to *O. circumcincta*.

The measurements in millimeters and the description of the species from 10 male and 10 female specimens along with Koffman's (1942) measurements in parenthesis, are reproduced below :

Diameter of head end 0.0175-0.022 ; location from the anterior end of nerve ring, excretory pore and cervical papillae at a distance of 0.23-0.3, 0.25-0.35 and 0.29-0.38, respectively; length of oesophagus 0.57-0.82 (600μ); maximum width of oesophagus 0.05-0.075 (40-50μ).

MALE : Body length 7.5-11 (7.5-8.5) ; maximum width in front of bursa 0.15-0.19 (125μ) ; length of spicules 0.26-0.32 (280-320μ) ; distance of point of division of the spicules from their distal ends 0.05-0.065 ; length of gubernaculum 0.09-0.12 (85μ) ; length of stem of dorsal ray 0.045-0.065 (40μ) ; length of branches of dorsal ray 0.035-0.06. The bursa conforms to the definition of the genus. The dorsal ray is bifurcated in its distal half into two branches with each branch showing distally bidigitate terminations. The spicules are dark yellowish brown in colour and comparatively slender. The spicules branch off distally into 3 processes, a broad main shaft and 2 short and slender processes. The main shaft is truncated and curved like a shepherd's hook while the other 2 branches have pointed ends. The branches of the spicules support large membranous expansion. The gubernaculum is lozenge shaped. The genital cone is marked by the presence of two triangular chitinous pieces separated by a median groove. The accessory bursal membrane is supported by 2 prominent rays.

FEMALE : Body length 9-14 (9.8-12.2) ; maximum width of body in the region of vulva 0.13-0.23 (150μ) ; length of tail 0.155-0.2 (150μ); combined length of ovejectors 0.54-0.76 ; distance between the posterior end and the vulva 1.72-3.8 (2) ; eggs, length 0.08-0.1 (95-105μ) , breadth 0.04-0.05 (40-50μ). The vulva is a transverse slit with 2 chitinous lips and is covered by a backwardly directed cuticular rounded flap. The tail is gradually tapering and ends in a slender rounded tip.

HOST. *Capra hircus, Ovis aries.*

LOCATION. Pyloric portion of abomasum.

LOCALITY. Murree, Choa Saidan Shah (West Pakistan) ; Mukteswar (India).

Schulz & Kadenatzii (1950) created the subgenus *Costarcuata* for the species *muraschkinzevi* on grounds of characteristic branching of spicules, quadrate shape of gubernaculum and the arc shaped dorsal ray *(Costarcuata)* of the bursa. The characteristics described by Schulz and Kadenatzii (1950) for the shape of the spicules and gubernaculum are fallacious as the shapes of both the structures are in complete conformity with those of the type *O. ostertagi*. The observations by Schulz & Kadenatzii (1950) on the shape of the dorsal ray are faulty in as much as the trunk of the dorsal ray joins the externo dorsal much more anteriorly than what is shown in their drawing (fig : 2). As all the characteristics observed in *O. muraschkinzevi* basically correspond to those of the genotype, *O. ostertagi*, there is no justification for holding the subgenus *Costarcuata*.

Ostertagia mossi Dikmans, 1931

(Figs. 19 & 20)

The species was described by Dikmans (1931) from Virginia deer *(Odocoileus virginianus)* from Pennsylvannia and this has remained, so far, the only record of the occurrence of this parasite. A collection from *Cervus* deer, lying in the Institute of Parasitology and Parasitic Diseases, Utrecht, contained some specimens of this species. In addition to this collection a single male specimen was discovered from the material collected from the stomach of a sheep from Kaghan Valley, Pakistan. The following description is based on specimens from Utrecht. The measurements are given in millimeters along with those of Dikmans (1931) which are quoted in parenthesis :

MALE. Body length 6-7(7) ; maximum body width in front of bursa 0.1-0.12(110μ) ; diameter of head end 0.018(0.016) ; nerve ring and cervical papillae situated, respectively, at a distance of 0.22-0.26 and 0.28-0.32 (320μ) from the anterior end ; length of oesophagus 0.6-0.72 (740-775μ) and maximum breadth at the distal end 0.06-0.064.

The spicules measured 0.21-0.26 (175-190μ) long and are light yellowish brown in colour. They are divided in their posterior fourth into three processes, a broad main shaft and two slender ones. The distal end of the main shaft is truncated while the other two porcesses are pointed. The gubernaculum is broad anteriorly and slender in its distal portion

and measured 0.065-0.08(60-70μ) long.

FEMALE : Body length 9-10 (9) ; breadth of head end 0.015 ; length of oesophagus 6.5 and its maximum breadth 0.05 ; nerve ring and cervical papillae at distances of 0.1 and 0.13, respectively, from the anterior end ; vulva at a distance of 1.6 from the distal end ; length of tail 0.19 ; eggs 0.075 x 0.04. The tail gradually tapers distally to end in a bluntly rounded tip which bears about eight transverse striations.

HOST : *Cervus* sp. *Ovis aries*.

LOCATION. Abomasum.

LOCALITY. Utrecht (Holland) ; Kaghan Valley (West Pakistan).

ii. **Stadelmannia** n.g.

Ostertagiinae : Male. Bursa comprising two large lateral and a distinctly marked median lobe ; ventral rays slightly unequal in thickness ; ventro-lateral, antero-lateral and medio-lateral of nearly equal thickness and thicker than the other rays ; antero-lateral and medio-lateral close together in their proximal and divergent in their distal portions ; the tips of the postero-lateral, only, reach the bursal margin ; dorsal ray medium in size, bifurcating a little posterior to its middle, and each branch showing an inner process near the tip and an outer process at a greater distance from the tip. Spicules split in their distal half into a thicker and longer, and one or more inner and shorter processes ; the distal end of the longer process truncated and enclosed in a hyaline membrane and that of shorter being pointed. Gubernaculum present. Genital cone complex in structure.

Female. Vulva covered by a backwardly directed hyaline striated flap.

Parasites of ruminants.

TYPE SPECIES : *S. circumcincta* (Stadelmann, 1894) = *Ostertagia circumcincta*.

The following species of the genus *Ostertagia* which conform to the above definition are transferred to the new genus *Stadelmannia :*

O. trifurcata, O. pinnata, O. turkestanica, O. harrisi, O. bakuriani, O. polarica, O. sp. (Rudakoff, 1937).

Stadelmannia circumcincta (Stadelmann, 1894)

(Figs. 21, 22 & 23)

A large material of the species was examined in order to determine

the range of length of spicules, as, *S. turkestanica* is being taken as a synonym of *S. circumcincta* inspite of differences in the lengths of the spicules in the two species. The material from the following collections was examined : three collections from sheep, England ; one collection from sheep, Cyprus ; three collections from sheep, Pakistan. Twelve male

Table showing measurements in millimeters of *Stadelmannia circumcincta*

	Ransom, 1911	Travassos, 1921	Gebauer, 1932	Material from Pakistan
Diameter of head end	0.018	—	0.018	0.018-0.02
Distance of nerve ring from anterior end.	a little in front of oesophagus	0.21	0.21	0.18-0.27
,, ,, excretory pore	neighbourhood of nerve ring	—	—	0.22-0.34
,, ,, cervical papillae from ant : end.	0.21-0.31	0.21-0.35	0.21-0.35	0.25-0.38
Length of oesophagus	0.5-0.64	0.5-0.64	0.5-0.64	0.57-0.73
Max : diameter oesophagus	0.04-0.05	—	—	0.045-0.075
Male				
Length of body	7.5-8 5	—	7.5-8.5	7.5-10
Maximum thickness	0.1-0.13	—	0.1-0.13	0.15-0.2
Length of stem of dorsal ray	0.05-0.06	0.050-0.068	0.05-0.07	0.045-0.055
Length of branches ,,	0.04	0.040	—	0.04-0.045
Length of spicules	0.32	0.28-0.32	0.28-0.32	0.33-0.37
Point of division of spicule from distal end.	—	0.052-0.060	0.05-0.06	0.075-0.09
Length of gubernaculum	0.09	0.084-0.09	0.08-0.09	0.09-0.105
Length of body of gubernaculum	1/3 portion	—	—	0.038-0.05
Length of posterior portion	2/3 portion	—	—	0.052-0 065
Maximum width of gubernaculum	0.03	0.030-0.032	—	0.022-0.03
Female				
Length of body	9.8-12.2	—	9-12	9-13
Maximum breadth of body	0.1-0.16	—	0.1-0 19	0.175-0.22
Location of vulva from the distal end.	1.9-2.3	1.5-2.5	1.5-2.5	1.81-2.36
Length of tail	0.13-0.16	0.13-0.16	—	0.14-0.18
Combined length of ovejectors	0.33-0.56	0 35-0.55	—	0.4-0.52
Egg, length	0.075-0.1	0.075-0.1	—	0.085-0.1
breadth	0.035-0.05	0,035-0.050	—	0.042-0.05

and twelve female specimens were thoroughly studied but only spicules were measured in another one hundred and ten specimens. A description of the material with measurements in millimeters, is as follows :

MALE : Body length 7.5-10 ; maximum thickness in front of bursa 0.15-0.2 ; diameter of head end 0.018-0.020 ; excretory pore, nerve ring and cervical papillae situated, respectively, at a distance of 0.22-0.29, 0.18-0.25 and 0.25-0.35 from the anterior end ; length of oesophagus 0.57-0.69 and its maximum width near the posterior end 0.045-0.070. Bursal rays conform to the bursal formula of the genus, dorsal ray divided into two

branches near its middle and each branch showing a short process near its middle on its outer side and another short process near its tip on the inner side.

The spicules measured 0.29-0.37 long and were found to bifurcate at a distance of 0.075-0.09 from the posterior end into the lateral and medial branches. The lateral branch forms a continuation of the main stem, terminating in a truncated end which is enclosed in a hyaline membrane, while, the medial branch is thinner and has a pointed distal end. No third process could be seen in any of the spicules dissected out of the body. More than one-third of the number of specimens, which were measured, showed a length of about 0.32. The gubernaculum, which is lozenge shaped or tennis racket shaped, measured 0.09-0.105 long, the broad proximal portion measuring 0.038-0.05 x 0.022-0.03 and the distal slender portion measuring 0.052-0.065 long.

FEMALE : Body length 9-13 ; maximum thickness in front of the vulva 0.175-0.22 ; diameter of head end 0.02 ; nerve ring, excretory pore and cervical papillae situated, respectively, at a distance of 0.2-0.27, 0.22-0.34 and 0.27-0.38 from the anterior end ; oesophagus 0.65-0.73 long and its maximum thickness 0.05-0.075.

HOST : *Ovis aries*.

LOCATION. Pyloric portion of abomasum.

LOCALITY. Peshawar (West Pakistan) ; Kangra (India).

Stadelmannia turkestanica (Petrow & Schachozewa, 1926)

(Fig : 24)

The species was originally described from sheep and goats from Usbekistan and Turkmenistan from U.S.S.R. The spicules in the species were described to measure 0.4095-0.4212* long and bifurcated into two equally long processes at a distance of 0.1092 from the distal end. The rest of the description of the species closely resembled that of *S. circumcincta*. Prof : Skrjabin, as quoted by Travassos (1937), in his "Les invasions vermineuses du mouton" stated that Gorbounov (1930) found *S. turkestanica* to be identical with *S. circumcincta*. Though the spicules were measured from as many as 110 specimens derived from Pakistan, Cyprus and England, the length of the spicules did not exceed 0.37. On the other hand, a single male specimen conforming to the description of *S. turkestanica* was found mixed with *O. muraschkinzevi* in a collection from goat at Murree. There were, however, no examples of *S. circumcincta* in the

* All measurements in millimeters

collection. The spicules were found, in the specimen, to measure 0.4 long and bifurcated at a distance of 0.1 from the distal end. The spicules have a dark yellowish brown coloration. Unfortunately the bursa in the specimen could not be thoroughly studied as it was not possible to unfold it without damaging the specimen.

HOST : *Capra hircus.*

LOCATION : Pyloric portion of abomasum.

LOCALITY : Murree (West Pakistan).

Bhalerao (1932) recorded the occurrence of *S. circumcincta* from goats at Mukteswar (India) but he did not give any description of the parasite. Daubney (1933) recorded the occurrence of *S. circumcincta* in sheep from Highlands of Kenya and he gave a short description of the material. The spicules in Daubney's specimens measured 0.28-0.32 long and, according to him, were found split distally into three processes, instead of two, as previously believed. The diagram of Daubney's *S. circumcincta* (fig : 9, 1933) does not show any resemblance to those of *S. circumcincta* of Ransom (1911), Travassos (1921), Gebauer (1932) and Saquenet (1947). Daubney (1933) found "large membranous expansion springing from the main shaft at the level of origin of the processes and extending beyond the tip (fig : 10)." The membranous expansion is not a feature of spicules in *S. circumcincta* and, instead, the expansion is very prominent in the spicules of *O. muraschkinzevi* with which the spicules of Daubney's *circumcincta* have a close resemblance. The author, however, tried to obtain Daubney's specimens of *circumcincta* and got in touch with him, but, Dr. R. Daubney was not in a position to supply the specimens. The author had the opportunity of examining some of Dr. Bhalerao's collection of *circumcincta* at the Indian Institute of Veterinary Research, Izatnagar, and found the specimens as identical with *O. muraschkinzevi*.

Stadelmannia trifurcata (Ransom, 1907)

(Fig. 25)

and

Stadelmannia pinnata (Daubney, 1933)

S. trifurcata and *S. pinnata* have a close similarity in the form of their spicules and have been mixed up in literature. The author found that *S. pinnata* occurred side by side of *S. trifurcata* in material from the abomasum of sheep in India and England. The finding of *S. pinnata* by the author forms the first record of *S. pinnata* in literature, after the

original description. The reasons for *S. pinnata* having remained obscure appear to lie in the fact that Daubney (1933) did not compare *S. pinnata* with the closely allied *S. trifurcata*. Instead, he compared it with *S. circumcincta* with which it has only a remote resemblance. It may even appear that

Table showing measurements in millimeters of *Stadelmannia trifurcata* (Ransom, 1907)

	Ransom, 1911	Travassos, 1921	Boulenger, 1914	Gebauer, 1932	Material from Pakistan
Body length of male	6.5-7	5-8.8	6-6.8	5-8.8	7.5-9
Diameter of head end	0.015	—	0.016-0.02	0.018	0.018-0.02
Length of oesophagus	0.46-0.48	0,46-0.56	0.48-0.49	0.46-0.58	0.52-0.63
Location of nerve ring from the anterior end.	0.23	0.21-0.24	0.21	0.21-0.24	0.22-0.26
,, ,, excretory pore	0.29	0.29	—	—	0.27-0.30
,, ,, cervical papillae	0.3	0.24-0.30	0.26	0.24-0.3	0.32-0.4
Length of dorsal ray	—	0.078-0.09	—	0.08-0.09	—
Length of stem of dorsal ray	0.04-0.05	0.04-0.05	0.035-0.04	0.04-0.05	0.045
Length of branches ,,	0.035-0.04	—	0.027-0.028	—	0.04-0.045
Length of spicules	0.15-0.18	0.15-0.21	0.15-0.16	0.15-0.18	0.18-0.22
Length of gubernaculum	0.07-0.09	0.070-0.10	0.062-0.065	0.07-0.1	0.09-0.1
Accessory bursal "lappen"	—	"bursal accessoria pequena"	—	0.015	0.02

Daubney (1933) was not aware of the description of *S. trifurcata*, and, *S. pinnata* has only an accidental validity. A comparison of *S. trifurcata* and *S. pinnata* shows that *S. trifurcata* is comparatively smaller and the two shorter branches of the spicules are thinner, tapering and sharply

Table showing measurements in millimeters of *Stadelmannia pinnata* (Daubney, 1933)

	Daubney, 1933	*S. trifurcata* of Kalantarjan, 1928	*S. trifurcata* ? of Saquenet, 1946	Material from Pakistan
Diameter of head end	0.02-0.024	0.02-0.022	0.019-0.022	0.02-0.022
Body length of male	7.0-8.5	—	8-9	10-11.5
Location of nerve ring from the anterior end.	—	—	—	0.2-0.3
,, ,, excretory pore ,,	—	—	—	0.28-0.39
,, ,, cervical papillae	0.37	—	—	0.37-0.45
Length of oesophagus	0.7-0.74	0.58-0.67	0.56-0.65	0.58-0.6
Length of dorsal ray	—	0.126-0.149	—	—
Length of stem	0.1	0.070-0.083	—	0.085
Length of branches	0.05	—	—	0.05
Length of spicules	0.22-0.265	0.21-0.25	0.225-0.295	0.25-0.265
Length of gubernaculum	—	0.095	0.095-0.1	0.13-0.15
Accessory bursal ray	—	0.04-0.042	—	0.04

pointed, while, the corresponding branches of spicules in *S. pinnata* end higher up in rapidly tapering sharp points. The spicules show considera-

ble differences in the range of size in the two species and the genital cones in the two species are markedly dissimilar. The comparative measurements in each of the two species have been tabulated. A scrutiny of the literature shows that *S. trifurcata* as described by Travassos (1921), Boulenger (1914) and Gebauer (1932) conforms to the original description of Ransom (1911), but, the description of *S. trifurcata* as given by Kalantarjan (1928) (as quoted by Gebauer, 1932) and that of Zarnowski (1949), conform to the description of *S. pinnata* by Daubney (1933). Saquenet (1946) working in Algeria, however, could not decide as to which of the two species his material belonged and described it as "*Ostertagia trifurcata*?". Saquenet (1946) overlooked the criterion of the genital cone but his drawing (Saquenet, fig. 10) showing the genital cone has an unmistakable resemblance to that of *S. pinnata*. The measurements quoted by Saquenet (1946), particularly of the spicules, however, correspond to those of *S. pinnata*. Schulz & Andreeva (1953) have figured the genital cones of some trichostrongylid worms and what they have purported to show under the caption *Ostertagia trifurcata* evidently represents, in fact, the genital cone of *Ostertagia pinnata*. On the other hand, the genital cone represented in their figure 2 (7-8), under the caption Trichostrongylinae gen. sp. III, has a perfect resemblance to the genital cone of *O. trifurcata*. The morphology of the spicules and genital cone in the two species has already been discussed by Sarwar (1954).

HOST : *Ovis aries, Capra hircus, Capra sibirica.*

LOCATION : Pyloric portion of abomasum.

LOCALITY : Murree, Kaghan Valley (West Pakistan) ; Dharamsala-Kangra (India).

iii. **Sjobergia** n. g.

Ostertagiinae. Male : Bursa comprising two large lateral and an indistinctly marked long median lobe ; ventral rays markedly unequal ; postero- and medio-laterals arising from a common trunk and diverging from the antero-lateral, the point of union of postero-lateral and the medio-lateral looking like a knee joint ; the tips of the medio -and postero-lateral, and, the two ventral rays, respectively, closer together than in any of the other two rays. The externo-dorsal is the thickest of all the rays and the ventro-lateral, antero-lateral and the medio-lateral rank next in order of thickness. The externo-dorsal is rapidly attenuated in its distal third. The dorsal ray is long with the trunk bifurcating in its distal fourth and each branch bearing a lateral process near its bifid termination ; spicules split behind their middle into three processes, viz : an outer thick with

the distal end enclosed in a hyaline membrane and two inner processes, one being pointed and the other obliquely truncated at the distal extremity. Gubernaculum present. Genital cone well developed.

Parasites of ruminants.

TYPE SPECIES : *Sjobergia lyrata* (Sjoberg, 1926) = *Ostertagia lyrata*

Other species besides *S. lyrata* that conform to the generic definition are as follows :

S. nemorhoedi (Schulz & Kadenatzii, 1950)

S. kolchida (Popova, 1937)

S. arctica (Mizkewitsch, 1929)

Sjobergia lyrata (Sjoberg, 1926) n. comb.

(Figs. 26 & 27)

The species was originally described by Agnes Sjoberg in 1926 from cattle in Austria. She named the species after the lyre-shaped character of the rays of the accessory bursal membrane. Dikmans (1931) recorded the parasite in cattle from Lousiana and corrected the original description of the posterior processes of the spicules and the accessory bursal membrane. The only measurements offered by Dikmans (1931) related to the dorsal ray which, according to him, had a stem measuring 90-95μ long and each of the branches measuring 13-15μ long.

Table showing measurements in mm. of *Sjobergia lyrata* (Sjoberg, 1929)

	Gebauer, 1932	Travassos, 1937		Material from Pakistan
		Compiled account	Original	
Diameter of head end	0.012-0.023	—	—	0.02-0.022
Distance of nerve ring from anterior end.	—	0.28-0.3	0.24	0.26-0.3
,, ,, excretory pore ,,	—	—	—	0.32
,, ,, cervical papillae	0.32-0.35	0.28-0.4	0.33	0.33-0.35
Length of oesophagus	0.51-0.71	0.51-0.98	0.66 0.83	0.70-0.73
Body length of male	9-12	8-12	—	6.5-7.0
Body width in front of bursa	0.145-0.200	0.14-0.24	—	0.14
Length of spicules	0.2-0.32	0.17-0.2	0.196-0.225	0.23-0.25
Length of gubernaculum	—	0.07-0.12	0.063	0.085-0.1
Body length of female	—	10-14.5	—	9
Body width in the region of the vulva	—	0.15-0.22	—	0.125
Distance between vulva and tail end.	—	2.2-3.0	1.3	1.4

Orloff (1933) transferred the species to his newly created subgenus *Grosspiculagia*. All the species grouped by Orloff (1933) under the subgenus

Grosspiculagia possess, in common, grossly thick spicules and long dorsal rays but the species can be divided into two distinct groups on the basis of character of externo-dorsal ray which is the thickest of all the rays in the *lyrata* group and thinnest of all the rays in *occidentalis*.

Gebauer (1932) recorded the species from *Rupicapra rupicapra* under the name of *Ostertagia occidentalis*. The discrepancy was noticed by Travassos (1937) who found that Gebauer's *occidentalis* perfectly conformed to the description of *lyrata*.

Travassos (1937) did not recognise the subgenus *Grosspiculagia* and he gave a description of the species *lyrata* from his material from Argentina.

The following description of the species is based on material from West Pakistan.

The spicules are thick and dark yellowish brown in colour and are divided at a distance of 0.1 mm. from the distal end into three processes. The outer or lateral process froms a prolongation of the main body of the spicule and its distal end is truncated and enclosed in a hyaline sheath. The distal end of one of the medial processes is pointed and the other has its distal end set off by a transverse ridge supporting a membrane. The gubernaculum has the shape of a dagger with proximal portion representing the handle. The bursal ray formula conforms to the generic definition of the bursa. The dorsal ray has a stem measuring about 0.115 mm. long and two short branches measuring 0.015 mm. each.

HOST : *Bos indicus*.

LOCATION : Pyloric portion of abomasum.

LOCALITY : Choa Saidan Shah (West Pakistan).

Sjobergia nemorhoedi (Schulz & Kadenatzii, 1950)

(Figs. 28 & 29)

The species was originally described by Schulz and Kadenatzii, 1950 from *Nemorhoedus goral* in U.S.S.R. and this has so far remained as the only record of the occurrence of this species. The parasite appears to be quite common in sheep and goats in Himalayas as all the ten collections examined from Murree contained the parasite in small numbers along with the predominating *Ostertagia muraschkinzevi*. The parasite was also found present in a collection from a goat at Mukteswar. The species differs from the closely allied *S. lyrata* by the differences in the shape of the genital cone, large foot of the outer process and the spicules in *S. nemorhoedi* being relatively longer.

The measurements in millimeters and the description of the species from the material from Pakistan, are as follows :

Body length 8-10 in the male and 11-13 in the female. Diameter of head end 0.02 ; nerve ring, excretory pore and cervical papillae situated, respectively, at distances of 0.2-0.3, 0.325-0.375 and 0.34-0.42 from the anterior end ; oesophagus 0.6-0.7 long. The spicules are thick, dark brown in colour and 0.25-0.28 long. They divide posteriorly in their middle into three branches viz, one lateral or outer which forms the main prolongation of the body and two medial or inner. The outer process has a truncated distal end enclosed in a hyaline pad and the two medial processes have pointed and ridged endings, respectively. The ridged end is marked off near the distal end by a transverse ridge supporting a hyaline membrane. The gubernaculum is 0.095-0.11 long. The bursal rays conform to the generic formula. The dorsal ray has a long stem measuring 0.13-0.135 long and the branches 0.05 long, each. Each of the branches bears a lateral process near its bifid ending.

Body width in the region of vulva 0.2 , vulva situated at a distance of 2.5 from the distal end ; tail 0.18 long ; combined length of ovejectors including infundibula 0.7-0.75.

HOST : *Ovis aries, Capra hircus, Capra sibirica.*

LOCATION : Pyloric portion of abomasum.

LOCALITY : Murree (West Pakistan) ; Kangra (Punjab-India) ; Mukteswar-Kumaon (U.P.-India).

Grigorian (1951) described *Rinadia schulzi* from *Capreolus capreolus*. The male tail of *S. nemorhoedi* has a striking resemblance with that of *R. schulzi* except that the long dorsal ray could not be observed by Grigorian (1951) in *R. schulzi*. I think the observations by Grigorian (1951) in regard to dorsal ray and gubernaculum are fallacious and both the structures will be found present on a re-examination of Grigorian's material of *R. schulzi*.

iv. **Gruhneria** n. g.

Ostertagiinae : Male. Bursa having two well developed lateral and a much reduced dorsal lobe ; ventral rays subequal ; ventro-lateral thickest of all the rays and antero-lateral and ventro-ventral ranking next in order of thickness ; postero-lateral thinner and longer than other laterals, gradually tapering distally and its tip reaching the bursal margin ; antero-

lateral and medio-lateral close together, diverging only near the tips ; postero-lateral divergent from the medio-lateral and the interval between the two rays greater than any of the other two rays ; dorsal ray very much reduced and bifurcated in its distal half. Accessory bursal membrane present. Spicules dark yellowish brown in colour, trifurcating in their distal third into an outer and two inner processes. The outer process which is the main prolongation of the body ends in a sharp pointed, keen edged, shoe-shaped termination, while, the two inner show pointed and truncated terminations, respectively. Gubernaculum absent.

Female : Vulvar flap poorly developed or absent ; tail thick at the proximal portion and a spike like projection on the distal portion ; vulvar sphincters poorly developed.

Parasites of ruminants.

TYPE SPECIES : *Gruhneria gruhneri* (Skrjabin, 1929)=*Ostertagia gruhneri*

The other species included in the genus is *G. bubalis* n. sp.

Gruhneria bubalis n. sp.

(Figs. 30, 31 & 32)

The species was collected from a buffalo calf which had lived throughout in the Jammu hills (Outer Himalayas). The description of the material, with measurements in millimeters, is as follows :

MALE : Body length 6.5-7 ; maximum width in front of bursa 0.09-0.11 ; diameter of head end 0.015-0.02 ; length of oesophagus 0.475-0.65 ; maximum width of oesophagus 0.04-0.05 ; nerve ring and excretory pore situated, respectively, at a distance of 0.22-0.23 and 0.23-0.24 from the anterior end. Spicules dark yellowish brown, measuring 0.15-0.175 long and dividing, at a distance of 0.05 from the distal end into an outer and two inner processes. Gubernaculum absent. The bursal ray formula conforms to the generic definition of the bursa.

FEMALE : Body length 8-9 ; maximum width near the vulva of 0.11-0.125 ; diameter of head end 0.02 ; length of oesophagus 0.65-0.7 and its maximum width near the distal end of 0.04-0.05 ; nerve ring and excretory pore situated, respectively, at a distance of 0.25-0.28 and 0.3-0.34 from the anterior extremity ; combined length of ovejectors about 0.3.2 ; eggs measuring 0.085-0.09 x 0.045-0.05.

HOST : *Bubalus bubalis*.

LOCATION : Pyloric portion of abomasum.

LOCALITY : Sheikhupura (West Pakistan).

This species differs from the only related species of the genus viz. *G. griihneri*, by the shape of its spicules and the size of its dorsal ray.

v. **Grosspiculagia** (Orloff, 1933)

Ostertagiinae : Male. Bursa having two large lateral and an indistinctly marked long median lobe ; ventral rays markedly unequal ; ventro-lateral, medio-lateral and antero-lateral of equal thicknesses and having equal intervals between them ; postero-lateral thinner than medio-lateral and its tip, lying at equal distance from externo-dorsal and medio-lateral, reaching the bursal margin ; externo-dorsal thinnest of all the lateral rays ; dorsal ray long and slender and its stem three times longer than the branches and each branch bearing a lateral process near its distal end ; spicules strongly built and split behind their middle into an outer and two inner branches, the outer and one of the inner branches being truncated at their distal ends and the other inner being pointed. Gubernaculum present. Genital cone of medium size.

Parasites of ruminants.

TYPE SPECIES : *Grosspiculagia occidentalis* (Ransom, 1907)=*Ostertagia occidentalis*

The other species besides the type species conforming to the above definition and included in the genus are as follows :

G. trifida (Guille, Marotel & Panisset, 1911)

G. skrjabini (Kamensky, 1929)

Grosspiculagia trifida (Guille, Marotel and Panisset, 1911)

(Fig. 33)

A single male specimen in a damaged condition was found in a collection, mixed with specimens of *Ostertagia muraschkinzevi*, from a goat from Kaghan valley. The bursa was found to be folded such that it could not be unfolded without the risk of seriously damaging it. The spicules in the specimen measured 0.32 mm. long and they were found to divide, at a distance of 0.18 mm. from the anterior end, into an outer and two inner processes. The outer process which forms a continuation of the body of the spicule, has a truncated distal end. The two inner processes (the dorsal inner and ventral inner) have truncated and pointed terminations, respectively. The inner dorsal process is, however, the thickest of the three processes and the inner ventral the thinnest. The dorsal ray is long and slender and bifurcates at a distance of 0.112 from its origin into two branches measuring 0.06 mm. each.

HOST : *Ovis aries*.

LOCATION : Pyloric portion of abomasum.

LOCALITY : Kaghan Valley (West Pakistan).

The identity of the three species, *G. trifida* (described from France), *G. occidentalis* (described from United States), and *G. skrjabini* (described from Russia) is a controversial issue. Orloff (1933) considered the three species to be identical. According to Travassos (1937), *G. occidentalis* appears to be different from *G. trifida* and *G. skrjabini*. However, the question of validity of the last two species remains an open one and the examination of the genital cones of the three species may help to decide this issue. The spicules, in the example from Pakistan, conform in appearance to *G. trifida* as well as those of *G. occidentalis* of Saquenet (1946) recorded by him from Algeria.

C. GEOGRAPHICAL DISTRIBUTION OF MEMBERS OF THE GENUS OSTERTAGIA S. LAT IN WEST PAKISTAN

The author, after an extensive survey of the Nothern and North-Eastern parts of the Province of West Pakistan found that Ostertagiines were restricted in their distribution to hilly tracts and no species of the genus *Ostertagia* or any of the related genera occurred in the vast alluvial plains. The hill tracts of the province comprise the following areas :

1. *Outer Himalayan Ranges*. The ranges form the North East boundary of the province, rising to a height of 7000 feet above sea level and receiving an annual rainfall of 50-80 inches (mostly in summer).

2. *Salt Range*. The ranges run from East to West, maintaining an average height of 2500 feet above sea level and receiving an annual rainfall of 20-30 inches (mostly in summer).

3. *Trans-salt Range Plateau*. North of salt range and rising to 1000-2000 feet above sea level and receiving an annual rainfall in summer of 10-30 inches.

The sheep and goats examined in these areas invariably harbour one or more ostertagiines though the combinations in which the species occurred varied from place to place. As a rule, the species were found to occur in the following sets of combinations :

1. Salt Range.	*O. ostertagi, O. muraschkinzevi, Sjobergia lyrata, Camelostrongylus mentulata, Marshallagia marshalli.*

2. Trans-Salt Range Plateau.	*O. ostertagi, Camelostrongylus mentulata.*
3. Outer Himalayas.	*O. muraschkinzevi, Sjobergia nemorhoedi, Stadelmannia trifurcata, Stadelmannia pinnata.*
4. Kaghan Valley. (Winter rainfall)	*S. circumcincta, Grosspiculagia occidentalis, M. marshalli, S. trifurcata, S. pinnata.*
5. Peshawar. (Winter rainfall)	*S. circumcincta, S. trifurcata, S. pinnata, M. marshalli.*

The foregoing distribution points out that *circumcincta* occurs only in the winter rainfall areas while *O. ostertagi* and *C. mentulata* are estricted to low hill tracts. The species *O. murashkinzevi* occurred as the commonest parasite in the Outer Himalayas.

IV. GENUS *TRICHOSTRONGYLUS* LOOSS, 1905

a. HISTORY

Looss (1905) created the genus *Trichostrongylus* and transferred the species, *Strongylus retortaeformis, S. instabilis* and *S. probolurus* to it and added, at the same time, the species *T. vitrinus* to the genus.

Ransom (1907) described the species *T. capricola* from sheep and goats in United States and transferred the species *Strongylus extenuatus* to the genus.

Nagaty (1932) redescribed most of the then known species under the genus.

The genus *Trichostrongylus,* as constituted at present, is composed of diverse forms and the present definition by Ransom (1911), being quoted below, does not cover all the species of the genus.

"Trichostrongylinae : cuticle of the anterior end may be raised into swellings. Cervical papillae absent. Buccal cavity ill defined. Bursa with relatively large lateral lobes but without well developed dorsal lobe. Ventral rays widely separated and of very different thicknesses; the ventro-ventral thin and ventrally directed, the latero-ventral thick, divergent from the ventro-ventral and close to the lateral rays. Postero-lateral thinner than, and divergent from, the remaining lateral rays, lying close to the externo-dorsal ray. Dorsal ray cleft near its tips, ending in short digita-

tions. Prebursal papillae small or absent. Spicules short, spoon or spatula shaped appearing twisted on account of ridges on their surfaces. An accessory piece present. Vulva typically with protruding lips. Eggs thin shelled, segmenting when deposited. Parasites in the alimentary tract of herbivores, rodents, birds and man."

TYPE SPECIES : *T. retortaeformis* (Zeder, 1800)

b. RECONSTRUCTION OF THE GENUS TRICHOSTRONGYLUS

(Fig. 34.)

A study of the species, *T. colubriformis, T. probolurus, T. axei, T. retortaeformis, T. longispicularis, T. vitrinus* and *T. rugatus* has shown that the morphological variability in the species of the genus, which can be employed in generic differentiation, is manifested in the following characters :

1. Form of gubernaculum.
2. Form and approximation of ventro-ventral and ventro-lateral rays.
3. Comparative thickness of antero-lateral and ventro-lateral rays.
4. The relationship of externo-dorsal and postero-lateral rays.
5. Form of dorsal ray.
6. Form of spicules.
7. Shape of the vulva and tail in the female.

As a result of these studies it was found that the species could be grouped in the following order :

Cobboldostrongylus n. g.	*T. axei, T. minor,* *T.* species (Pogorshkovu).
Probostrongylus n. g.	*T. probolurus, T. hamatus.*
Gilesia n. g.	*T. colubriformis, T. longispicularis, T. pietersi, G. ovis* sp.n.
Buckleya n. g.	*T. vitrinus, T. leiperi.*

The reasons for creating four new genera may be summarized as follows :

1. *Cobboldostrongylus* n. g.

1. The medio-lateral and postero-lateral rays are of equal size.
2. The tips of medio- and postero-lateral rays are closer together

than in any other two rays and the tip of the latter reaches the bursal margin.

3. The spicules are comparatively slender and dissimilar.
4. The gubernaculum has a highly characteristic shape, its proximal portion curved and its distal portion straight.
5. The ventro-ventral ray shows a characteristic spiral curve in its course.
6. The vulva shows thick cuticular lips which are characterised as sausage shaped.
7. The end of the tail is rounded.

According to the definition of the genus *Trichostrongylus*, the postero-lateral ray is thinner than, and divergent from the remaining lateral rays and lies close to the externo-dorsal ray. On the other hand, in the species placed under the new genus the medio-and postero-lateral rays are of equal size and their tips closer together than in any other rays. The spirally twisted shape of the ventro-ventral ray in *axei*, *minor* and Pogorshkovu's species (in Skrjabin *et al* 1952) is highly characteristic. The shape of ventro-ventral ray in *T. axei* is constant in materials fixed in both alcohol as well as formalin and is evident in drawings of the bursa by other workers, such as, Ransom (1911), Gebauer (1932), Travassos (1921) and Zarnowski (1949). In *T. minor* the bursa was described by Monning (1932) as "of the same type as seen in *T. axei*".

2. *Gilesia* n. g.

1. The tips of externo-dorsal and postero-lateral are close and the tip of the postero-lateral is characteristically bent. In the type species, *T. retortaeformis*, the tip of the postero-lateral lies midway between the externo-dorsal and the medio-lateral.
2. The antero-lateral is the thickest of the rays in the bursa.
3. The dorsal ray is characteristic bearing an outer process and further back a papilla like inner process an each of its branches.
4. The distal portion of the spicules are barbed.
5. The gubernaculum is very characteristic with its proximal extremity being curved.
6. The tail end in the female is sharp pointed.
7. The vulva is different in shape from that of the type and the other members of the genus *Trichostrongylus* sensu lato.

3. *Buckleya* n. g.

1. The proximity of the ventro-ventral with the ventro-lateral ray is very characteristic, the two rays being relatively close and the ventro-ventral ray being comparatively large.
2. The externo-dorsal ray is thickened at its proximal portion and it is bent at its termination. The postero-lateral ray is almost straight and nearly reaches the edge of the bursa.
3. The dorsal ray has a characteristic appearance at the points of termination of its branches.
4. The spicules have smooth outlines.
5. The gubernaculum is comparatively straight and does not show marked depressions in its course.
6. The vulva is markedly different from that of any other species. It is obliquely located and not crescentic and longitudinal as described by Nagaty (1932).
7. The shape of the tail is characteristic. It rapidly tapers ventrally from the point af anus to end in a blunt point.

4. *Probostrongylus* n. g.

1. The externo-dorsal ray is remarkably short and slender and its course is straight and parallel to the dorsal ray.
2. The dorsal ray has a gradually tapering stem which thickens near the distal end to divide into two outer and two inner processes and each of the inner processes shows a papilla-like projection on the outer side in their middle.
3. The spicules have a twisted or gnarled appearance.
4. The gubenaculum is typically spindle shaped with long limbs unlike the gubernaculum of *T. retortaeformis* which is boat shaped.
5. The female has a highly characteristic posterior portion which is plump and rapidly diminishes behind the anus to form a short blunt tail.

i. **Trichostrongylus** Looss, 1905

A short description of the type species, *T. retortaeformis* which was studied from specimens recovered from a rabbit in the London School of Hygiene and Tropical Medicine, is reproduced below for comparison with the newly created genera.

Trichostrongylus retortaeformis (Zeder, 1800)

(Fig. 35)

The species appears to have a greater resemblance with *T. affinis* (the species described from wild rabbit) than with any other *Trichostrongylus* spp.

The distal free ends of the bursal lobes are inwardly curled. The ventro-ventral ray is thin and directed ventrally and is widely separated from the ventro-lateral which is thick and close to the laterals. The ventro-lateral and the antero-lateral are the thickest of all the rays with the medio-lateral and postero-lateral ranking next in order of thicknesses. The tips of the antero-lateral and the medio-lateral are closer together than in any other two rays. The externo-dorsal is curved towards the dorsal and its tip lies between the tip of the dorsal and that of the postero-lateral. The dorsal ray has a long trunk which is bifurcated near the distal end and each of the branches bidigitate.

The spicules are coarsely built, bent longitudinally and bluntly rounded at the distal extremities. The spicules show conspicuous longitudinal grooves running channel-like from the middle thirds to their distal ends. An accessory groove can be made out on the ventral side of each of the spicules near the distal extremity. The gubernaculum, when viewed dorso-ventrally, appears broad and lightly chitinised.

The tail, in the female, tapers gradually from a point where the posterior ovary bends forward, to end in a blunt point.

ii. **Gilesia** n. g.

Trichostrongylinae. Bursa well developed ; ventro-ventral ray thin and widely separated from the ventro-lateral ; ventro-lateral ray close to the laterals and equal in thickness to the medio-lateral and next in thickness to the antero-lateral which is the thickest of all the rays ; postero-lateral much thinner than the other laterals, widely divergent from the medio lateral and close to the externo dorsal and bent at its distal termination ; the distances being close and equal between the tips of externo-dorsal and postero-lateral and medio-and antero-lateral, respectively, there, again, being equal distances between the tips, respectively, of postero-lateral and medio-lateral, and dorsal and externo-dorsal ; dorsal ray medium in size ; spicules bent ventrally and barbed at their posterior quarters and bluntly pointed at their distal end ; gubernaculum, if viewed laterally, obliquely situated and showing a large proximal and a small distal curve, and twisted at the proximal termination.

Vulva longitudinal and crescentic in shape ; the tail of the female sharply pointed.

Parasites of ruminants.

TYPE SPECIES : *G. colubriformis* (Giles, 1892) *(=Trichostrongylus colubriformis).*

Gilesia longispicularis (Gordon, 1933) n. comb.

(Figs. 37 & 38)

A single male specimen was recovered from each of the two collections from sheep from Peshawar, the other *Trichostrongylus* spp. present being *colubriformis, probolurus, axei* and *vitrinus,* the last species being present in preponderating numbers.

The species was originally described by Gordon (1933) from a single male specimen collected from the intestine of a sheep in Australia. Andrews (1934) reported the species from three male specimens collected from fourth stomach of cattle at Jeanerette, Lousiana. Andrews (1935) reported the species again from a single male specimen found in a cow in Florida. Schulz and Kadenatzii (1950) recorded the species from *Nemorhoedus goral* from U. S. S. R. Dr. R. Swierstra of the Institute of Parasitology and Parasitic Diseases, Utrecht, Holland, showed the author some specimens of the species collected by him from cattle in Holland. The species, however, appears to be cosmopolitan in occurrence, though collected in small numbers on each occasion.

Gordon (1933) contributing to the differential diagnosis of *longispicularis* stated that "this species bears no very close resemblance to any of the recorded species from ruminants the length and form of the spicules and the asymmetrical structure of the dorsal ray being distinctive." Le Roux (1950) challenged the validity of the species from its published account stating that he had in his collections specimens of *colubriformis* having spicules measuring as long as of *longispicularis* but he did not discuss the relative conformation of the spicules in the two species. The conformation of the spicules in the two species is different, there being prominent triangular hooks at the posterior thirds of the spicules in *colubriformis* but the hooks are inconspicuous in *longispicularis.*

The measurements in millimeters of specimens from Pakistan are detailed in the following comparative table :

	Gordon, 1933	*Andrews, 1934/35*	*Pakistan*
Body length	5.5	5.6, 4.85	3.66, 3.85
Max. body width	0.113	0.098,0.088	0.135,0.1

Cantinued.

	Gordon, 1933	*Andrews, 1934/35*	*Pakistan*
Width at head end	0.014	0.01,0.01	0.012,0.01
Length of spicules	0.184	Right 0.175-0.18,0.168	0.18,0.165
		Left 0.19,0.175	0.19,0.165
Length of hook like projections	—	0.04-0.05	0.038-0.043
Length of gubernaculum	0.085	0.09,0.085	0.09,0.09
Length of oesophagus	—	—	0.65,0.67
Distance of excretory pore	—	—	0.11,0.1

The bursa corresponds to the generic type. The dorsal ray is asymmetrical in distal branching but the form of division of the branches corresponds to that of *colubriformis*.

HOST : *Ovis aries*

LOCATION : Duodenum.

LOCALITY : Peshawar, Kaghan Valley (West Pakistan).

Gilesia ovis n. sp.

(Fig. 39)

A single male specimen measuring about 4 mm. long was found in a collection from the intestine of a sheep from Chiniot, West Pakistan. The spicules in the specimen are yellowish brown in colour and measured, respectively, 0.12 and 0.14 mm. long. The gubernaculum measured 0.065 mm. long and is essentially of the same form as defined in the genus. The barbs on the spicules were found located at a distance of 0.034 mm. from the distal end but they are not equally prominent in both the spicules. The bursa corresponds to the generic pattern.

HOST : *Ovis aries*.

LOCATION : Duodenum.

LOCALITY : Chiniot (West Pakistan).

The species differs from its closely allied species *colubriformis* by the shape and smaller size of its spicules.

iii. **Buckleya** n. g.

Trichostrongylinae : Bursa very well developed ; antero lateral slightly wider than the ventro lateral ; ventro lateral slightly divergent from the ventro ventral ; postero lateral ray long, narrow and almost

straight and diverging from the medio lateral and nearly reaching the edge of the bursa ; externo dorsal thick at the proximal portion and its distal end bent towards the dorsal ray ; dorsal ray distally bifurcated and each of the bifurcations showing inconspicuous papillae at its termination. Spicules smooth in outlines ; gubernaculum, if viewed laterally, showing two equal arc shaped shallow concavities.

Vulva placed diagonally to the long axis of the body ; tail in the female reduced rapidly on the ventral side behind the anus.

Parasites of ruminants.

TYPE SPECIES : *B. vitrinus* (=*Trichostrongylus vitrinus* Looss, 1905)

Buckleya vitrinus (Looss, 1905) n. comb.

(Fig. 40)

A short description from Pakistani material with measurements in millimeters is as follows :

MALE : Body length 4-5 ; excretory pore 0.14-0.17 from the head end; length of oesophagus 0.74-0.85 ; length of spicules and gubernaculum 0.15-0.18 and 0.072-0.085, respectively. The spicules end posteriorly in very sharp points and there are no hook like projections on their bodies.

The bursa corresponds to the generic pattern.

FEMALE : Body length 6-7 ; length of the tail 0.08-0.09.

HOST : *Ovis aries*.

LOCATION : Duodenum.

LOCALITY : Peshawar (West Pakistan).

iv. **Cobboldostrongylus** n. g.

Trichostrongylinae. Bursa with two well developed lateral and an indistinct dorsal lobe. Ventro-ventral ray thin and spirally curved ; ventro-lateral and antero-lateral and medio- and postero-laterals, of equal thicknesses and the tips of the latter two rays closer together than any of the other two rays ; dorsal and externo dorsal long and thinner than the laterals ; dorsal ray longer than the exteno-dorsal and showing two bidigitate divisions at the distal end ; spicules short, slender and dissimilar ; gubernaculum, if viewed laterally, showing a curved proximal and a straight distal portion.

Vulva bounded by thick cuticular lips ; tail in the female rounded.

Parasites of ruminants.

TYPE SPECIES : *C. axei*=*Trichostrongylus axei* (Cobbold, 1879)

Cobboldostrongylus axei (Cobbold, 1879) n. comb.

(Figs. 41-44)

The species is extremely common in sheep, goats and cattle in the cooler regions of Pakistan. The author also collected the species from a chinkara deer (*Gazella benetti)* and mountainous sheep (*Ovis nahura)* which had died in the Zoological Gardens, Lahore.

A short description of the species from material from Pakistan, along with measurements quoted in millimeters, is as follows :

MALE : Length 3-3.5 ; body width in front of bursa of 0.050-0.065 ; spicules dissimilar and dark brown in colour, the left measuring 0.098-0.12 long and the right 0.079-0.092 ; gubernaculum measuring about 0.06 long with a swollen middle portion and two limbs of which the proximal is bent dorsally.

The bursa conforms to the generic pattern. The dorsal ray measured 0.045-0.06 long.

FEMALE. Body length 3.5-5.0 ; maximum diameter in the region of the vulva of 0.045-0.052. The vulva is a crescentic longitudinal slit and is bounded by two thick sausage shaped cuticular lips. The ovejectors measured 0.25-0.28 long and the tail 0.065-0.074 long.

HOSTS : *Capra hircus, Ovis nahura, Gazella benetti, Bos indicus.*

LOCATION : Abomasum and duodenum.

LOCALITY : Murree, Salt Range tract, Peshawar (West Pakistan).

v. **Probostrongylus** n. g.

Trichostrongylinae. Bursa with well developed lateral lobes ; ventro ventral thin and very divergent from the ventro lateral ; ventro-lateral thickest of all the rays with antero-lateral and medio-lateral ranking next in order of thickness ; postero-lateral and externo-dorsal remarkably short and close to each other ; dorsal ray short with a gradually tapering trunk and divided near its termination into two outer and two inner processes, each inner process, in turn, bearing on its outer surface a papilla-like projection. Spicules twisted or gnarled ; gubernaculum spindle shaped.

FEMALE : Body plump in the posterior half, diminishing rapidly in thickness behind the anus to form a highly characteristic blunt tail.

Parasites of ruminants.

TYPE SPECIES : *P. probolurus=Trichostrongylus probolurus* (Railliet, 1896)

Probostrongylus probolurus (Railliet, 1896) n. comb.

(Fig. 45)

The species is very common in sheep and goats in the Punjab and also occurred in two chinkara deers *(Gazella benetti)* which had died in the Lahore Zoological Gardens.

A short description of the species, with measurements in millimeters, is as follows :

MALE : Body length 4.5-5.5 ; body width in front of bursa 0.08 ; spicules dark brown in colour, measuring 0.12-0.13 long and showing on their ventral surfaces two prominent angular projections, each ; gubernaculum dark brown and measured 0.07-0.075 long. Bursa conforms to the generic pattern. The dorsal ray measured 0.040-0.045 long.

FEMALE : Body length 4.5-6 ; body width in the region of the vulva 0.08 ; combined length of the ovejectors 0.37 ; eggs measuring 0.076-0.08 x 0.043-0.046.

HOST : *Capra hircus, Ovis aries, Gazella benetti.*

LOCATION : Abomasum and duodenum.

LOCALITY : Lahore, Peshawar (West Pakistan).

Probostrongylus hamatus (Daubney, 1933)

The species is being included under the new genus *Probostrongylus* on the basis of its description as the original material could not be made available for study. According to Daubney (1933) the bursa and female tail of *P. hamatus* are very similar to that of *P. probolurus*. Similarly, the spicules and gubernaculum as represented by Daubney (1933) in his drawings of *P. hamatus*, have a close similarity with those of *P. probolurus*.

C. GEOGRAPHICAL DISTRIBUTION OF MEMBERS OF THE GENUS TRICHOSTRONGYLUS SENSU LATO IN INDO-PAKISTAN

Very little information is available on the geographical distribution of trichostrongyles in Indo-Pakistan. *Trichostrongylus colubriformis* is known to occur in Madras (Rao, 1940) Assam and Punjab (Giles, 1892) and Poona and Mukteswar (Bhalerao, 1942). Bhalerao (1935) found *colubriformis* to be of rare occurrence in India.

Trichostrongylus probolurus was recorded by Nagaty (1932) from a single male from Giles collection of *colubriformis* deposited in the British Museum (Natural History).

Trichostrongylus axei was recorded by Bhalerao (1942) from a few specimens from a goat at Mukteswar. Little else is known on the geographical distribution of the trichostrongyles in the subcontinent.

The author's experience in West Pakistan shows that *colubriformis* and *probolurus* are very common in sheep and goats in the plains and *axei* very common in ruminants in the hills. The species *vitrinus* and *longispicularis* were, however, found restricted to the northernmost areas. Since the trichostrongyle fauna from the northernmost part of the province shows differences from the rest of the subcontinent, it may be interesting to give in the following lines a short account of the topography of Peshawar and Mardan Districts which constitute the northernmost tract.

Peshawar lies between 33°43′ and 34°32′ N. It is a vast plateau and a huge basin into which flow the waters from the surrounding hills. Geologically, the formations consist of shales and sandstones of marine origin. The temperature sometimes falls below 30 and the nights are intensely cold. Annual rainfall is $17\frac{1}{2}$ inches and of this 11 inches fall in summer and $6\frac{1}{2}$ inches in winter.

A good winter rainfall has been reported to favour the trichostrongyles (Gordon, 1950). In experiments carried out by Rogers (1940) *Trichostrongylus* spp. reached maximum activity at 15 C and it appears that in the cooler months the amount and incidence of rainfall largely determines the magnitude of trichostrongyle infestation. In India, *T. colubriformis* has been reported to occur in regions which are climatically contrasting and range from extremes of climate to more or less uniform conditions throughout the year. The species *probolurus* is at present known to occur only in West Pakistan where it is very common. The rest of the trichostrongyles viz : *axei, vitrinus* and *longispicularis* conform in distribution to the epidemiological factors pointed out by Rogers (1940) and Gordon (1948).

SUMMARY

1. The significance of two of the morphological characters, viz : shape and organization of ventral rays of the bursa and pattern of the cuticular markings on the bursal membrane af lateral lobes, is discussed. Evidence has been presented on the basis of a survey of the organization of ventral rays and a detailed study of the patterns of cuticular markings on the bursal membranes that these characters have an important bearing on taxonomic grouping.

A new family Ostertagiidae and a new subfamily Ostertagiinae have been proposed as a result of these observations.

2. The genus *Ostertagia* has been split up and three new genera proposed. The subgenus *Grosspiculagia* has been raised to the status of a full genus. The following species of the genus *Ostertagia s. lat.* have been recorded for the first time from the Indo-Pakistan Sub-continent : *muraschkinzevi, nemorhoedi, mossi, lyrata* and *occidentalis.* A new species *Gruhneria bubalis* has been described from a buffalo from the subcontinent. Evidence has been brought forth to show that *muraschkinzevi* and *circumcincta* on one hand and *trifurcata* and *pinnata* on the other have been badly mixed up in literature.

3. The genus *Trichostrongylus* has been split up and four new genera, viz., *Cobboldostrongylus, Probostrongylus, Gilesia* and *Buckleya* proposed. The species *vitrinus* and *longispicularis* have been recorded for the first time from the subcontinent and a new species *Gilesia ovis* described from sheep. The geographical distribution of *Trichostrongylus* spp. ***sensu lato*** has been described.

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EXPLANATION OF FIGURES

Fig. 1. Drawings of a lateral lobe of copulatory bursa showing markings on the bursal membrane. *a.* specimen after fixation in 10% formalin; *b.* specimen afte fixation in 70% alcohol.

Fig. 2. Drawings showing markings on the membrane of the copulatory bursa.

Fig. 3. Drawings showing the shape and organization of ventral rays of copulatory bursa.

Figs. 4 & 5. Drawings showing markings on the lateral lobes of copulatory bursa.

Figs. 6 & 7. Drawings showing the shape and organization of ventral rays of copulatory bursa.

Fig. 8. Drawings showing markings on the membrane of lateral lobes of copulatory bursa.

Fig. 9. Drawings showing the shape and organization of ventral rays.

Fig. 10. Drawings showing markings on the membrane of lateral lobe of copulltory bursa. (for comparison with groups I—III)

Figs. 11—14. Drawings showing the shape and organization of ventral rays. (for comparison with groups I—III)

Fig. 15. Drawing showing a comparison of the criteria used for differentiation of the new genus *Stadelmannia*. The scales of measurements apply to the corresponding parts on both sides.

Fig. 16. *Ostertagia ostertagi*. *a.* spicule and gubernaculum; *b.* distal end of male; *c.* ventral view of genital cone; *d.* dorsal view of genital cone; *e.* gubernaculum.

Fig. 17. *Ostertagia ostertagi*. *a.* tail end; *b.* vulva and ovejectors.

Fig. 18. *Ostertagia muraschkinzevi*. *a.* anterior extremity; *b.* & *d.* spicules in different aspects; *c.* gubernaculum; *e.* distal ends of spicules as protruded out of cloaca; *f.* distal ends of spicules in different aspects; g. lateral view of bursa; *h.* dorsal ray; *i.* & *j.* dorsal and ventral views of cloaca; *k.* vulvar sphincters; *l.* tail of female; *m.* vulva and ovejector.

Fig. 19. *Ostertagia mossi*. Male; *a, b.* & *c.* spicules in different aspects; *d.* copulatory bursa; *e.* dorsal ray and genital cone; *f.* spicules and gubernaculum from a specimen from sheep, Pakistan.

Fig. 20. *Ostertagia mossi*. Female, *a.* tail end; *b.* vulva and ovejectors.

Fig. 21. *Stadelmannia circumcincta*. Male, *a.* spicules and gubernaculum; *b.* distal end of spicule; *c.* proximal end of spicule; *e.* gubernaculum in different aspects. *f.* genital cone.

Fig. 22. *Stadelmannia circumcincta*. *a.* anterior extremity; *b.* copulatory bursa

Fig. 23. *Stadelmannia circumcincta*. Famale, *a.* Vulva and ovejectors; *b.* tail end.

Fig. 24. *Stadelmannia turkestanica*. Spicules.

Fig. 25. *Stadelmannia trifurcata*. Bursa.

Fig. 26. *Sjobergia lyrata*. Spicules and gubernaculum.

Fig. 27. *Sjobergia lyrata*. Copulatory bursa.

Fig. 28. *Sjobergia nemorhoedi*. Spicules and gubernaculum in different aspects.

Fig. 29. *Sjobergia nemorhoedi*. Copulatory bursa and genital cone.

Fig. 30. *Gruhneria bubalis*. Spicules.

Fig. 31. *Gruhneria bubalis*. Copulatory bursa.

Fig. 32. *Gruhneria bubalis*. *a*. female tail ; *b*. vulva and ovejectors.

Fig. 33. *Grosspiculagia occidentalis*. Spicules.

Fig. 34. Gubernaculum ; a. *axei*, b. *colubriformis*, c. *vitrinus*, d. *probolurus*. Ventral rays ; e. *axei*, f. *colubriformis*, g. *vitrinus*, h. *probolurus*. Externo-dorsal and postero-lateral rays. i. *axei*, j. *colubriformis*, k. *vitrinus*, l. *probolurus*.

Fig. 35. *Trichostrongylus retortaeformis*. *a*. copulatory bursa ; *b*. spicules and gubernaculum.

Fig. 36 a. *Gilesia colubriformis*. Copulatory bursa.

Fig. 36 b. *Gilesia colubriformis*. *a*. female tail, *b*. vulva and ovejectors.

Fig. 37. *Gilesia longispicularis*. Spicules and gubernaculum.

Fig. 38. *Gilesia longispicularis*. Tail end of male.

Fig. 39. *Gilesia ovis*. Tail end of male.

Fig. 40 A. *Buckleya vitrinus*. *a*. spicules ; *b*. copulatory bursa.

Fig. 40 B. *Buckleya vitrinus*. *a*. vulva and ovejectors ; *b*. female tail.

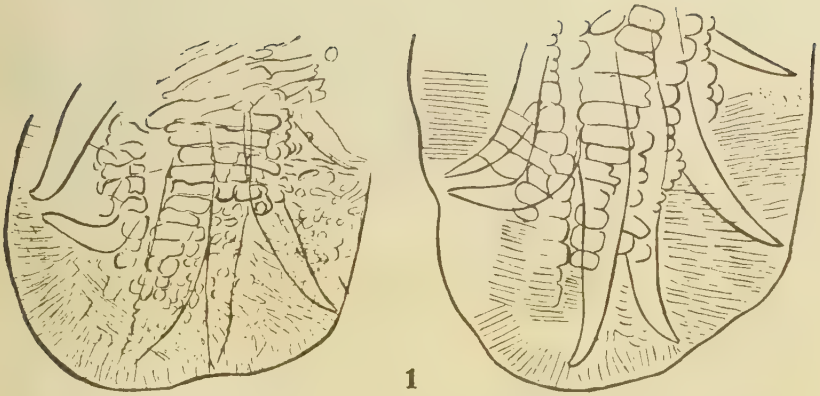
Fig. 41. *Cobboldostrongylus axei*. *a*. vulva ; *b*. copulatory bursa ; *c*. spicules and gubernaculum.

Fig. 42. *Cobboldostrongylus axei*. Copulatory bursa.

Fig. 43. *Cobboldostrongylus axei*. Lateral view of copulatory bursa.

Fig. 44. *Cobboldostrongylus axei*. *a*. vulva and ovejectors ; *b*. tail end of female.

Fig. 45. *Probostrongylus probolurus*. *a*. spicules and gubernaculum ; *b*. copulatory bursa ; *c*. tail end of female ; *d*. egg ; *f*. dorsal ray of *G. colubriformis*.

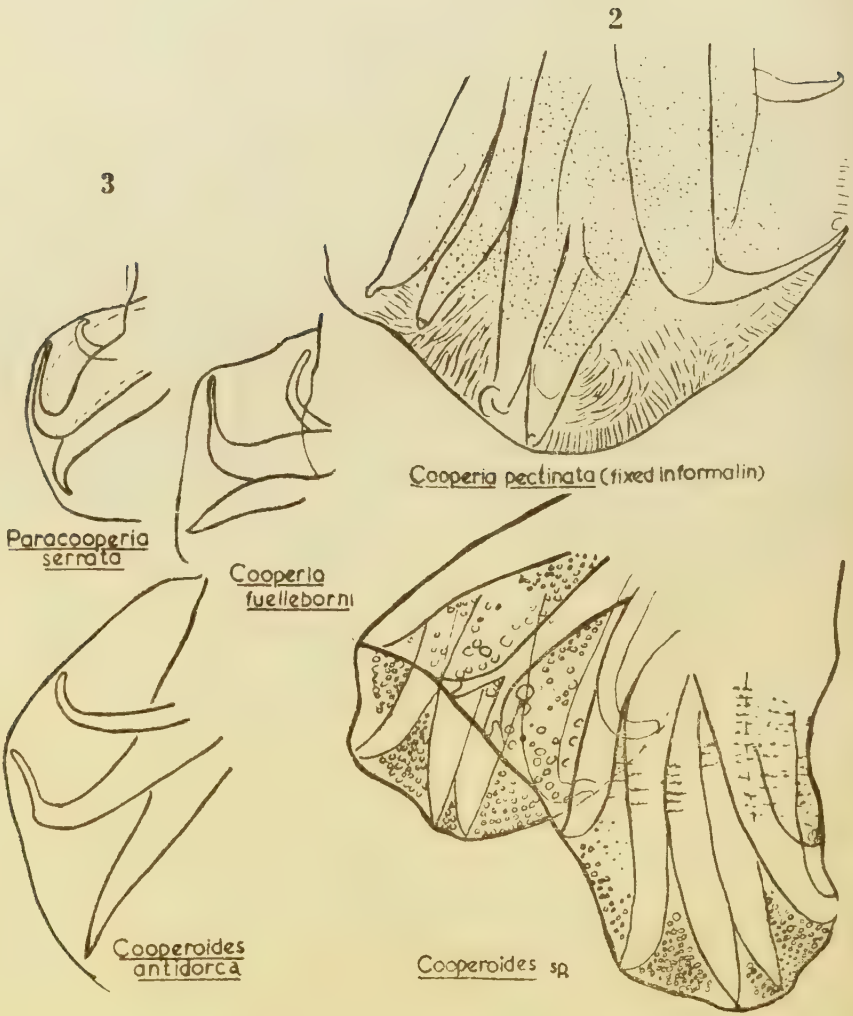


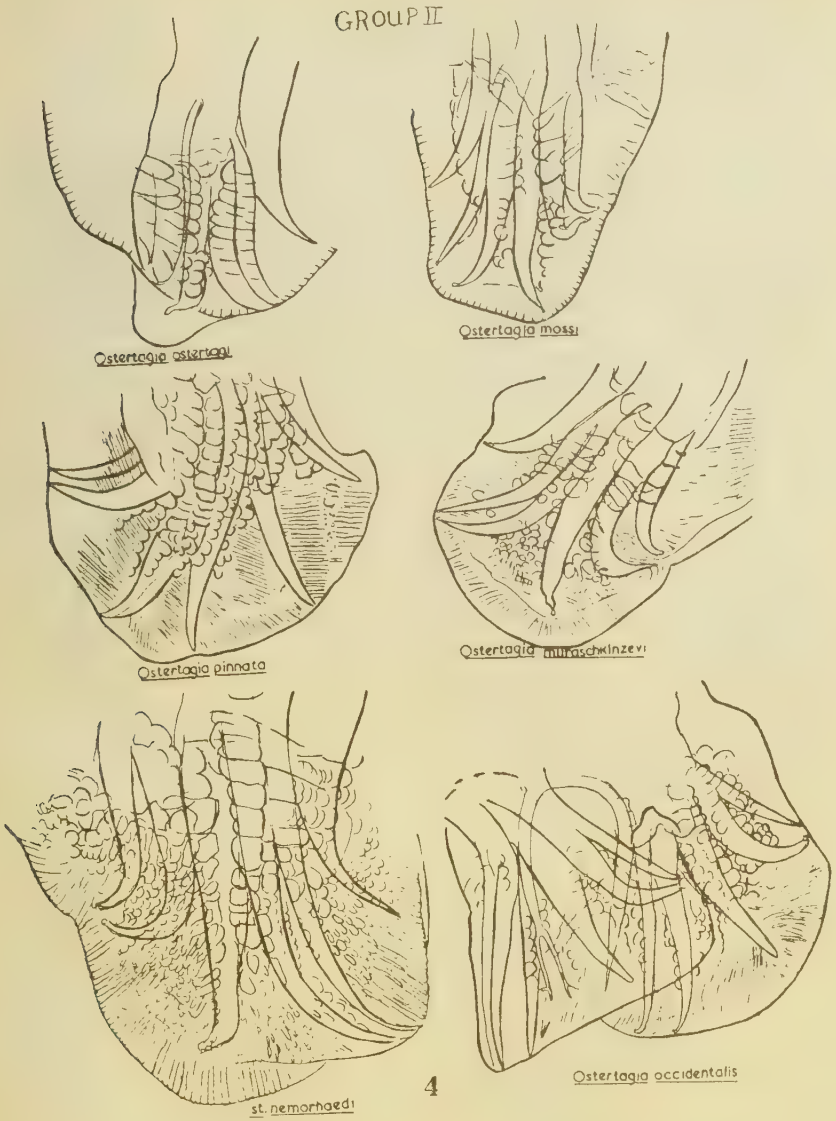
(a) (b)

1

Ostertagia circumcincta

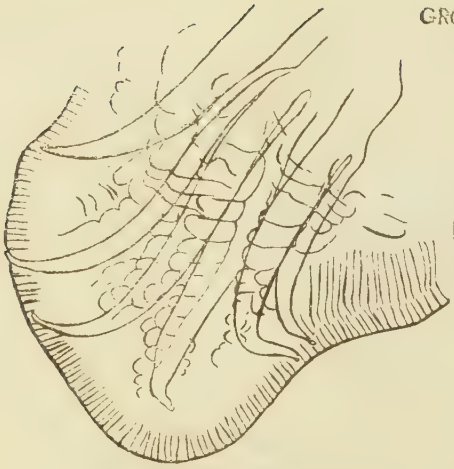
GROUP I


2
3
Cooperia pectinata (fixed in formalin)
Paracooperia serrata
Cooperia fuelleborni
Cooperoides antidorca
Cooperoides sp.

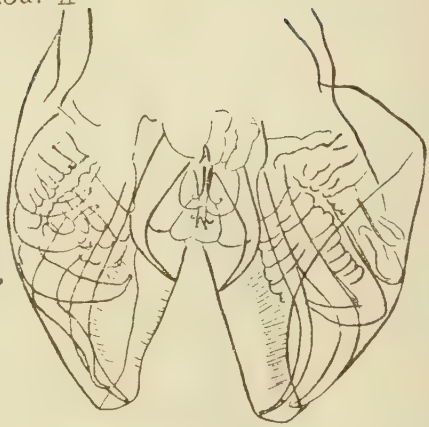

GROUP II
Ostertagia ostertagi
Ostertagia mossi
Ostertagia pinnata
Ostertagia kolchidensis
Ostertagia occidentalis
st. hemorhagei

4

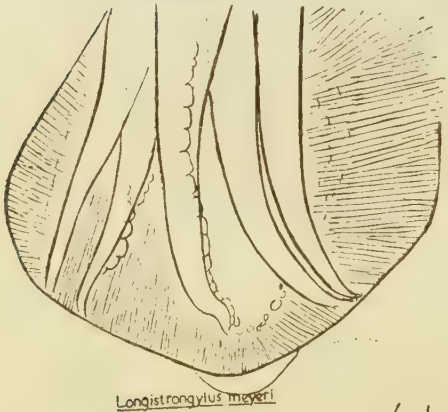
GROUP II



Ostertagia lyrata

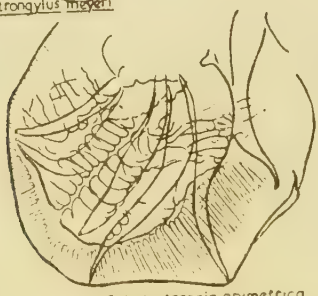


Camelostrongylus mentulata



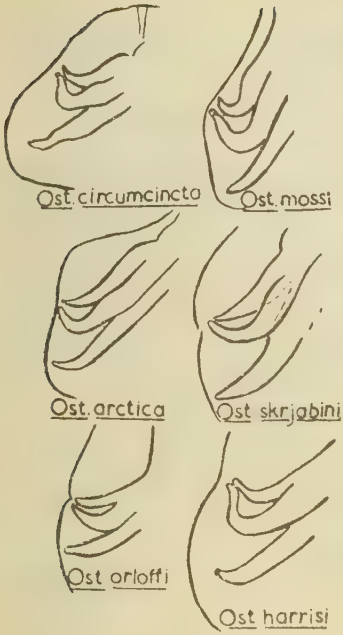
Longistrongylus meyeri

Marshallagia marshalli



Spiculopteragia asymetrica

5



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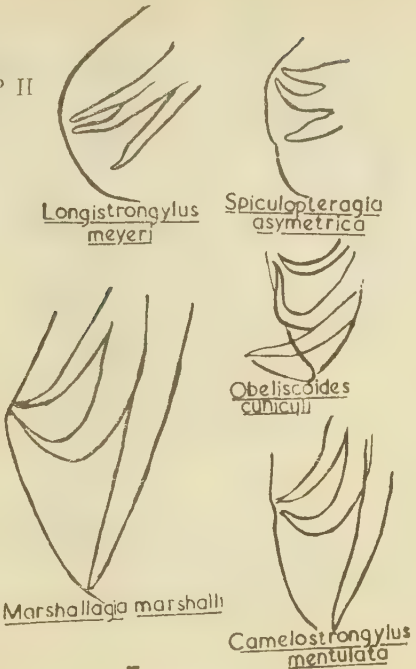
GROUP II



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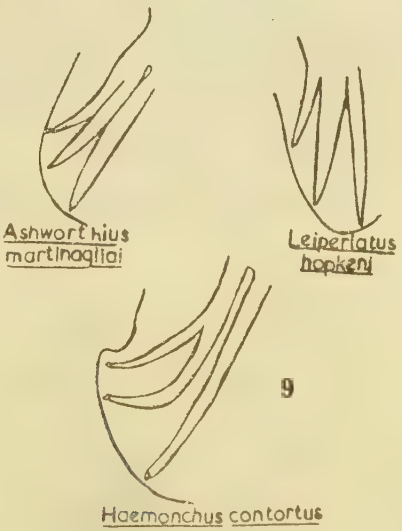
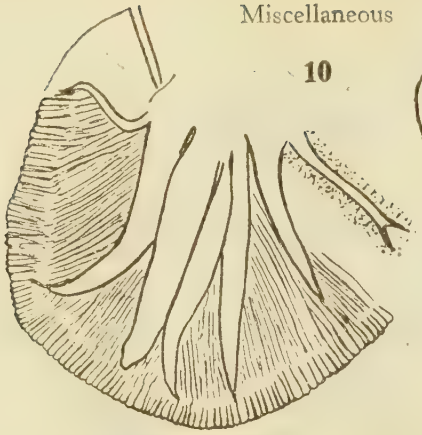
GROUP III



9

Miscellaneous

10



Trichostrongylus axei

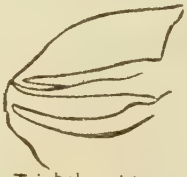
Molineus felineus

Adolpholutzia lutzi

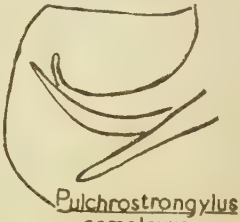
Monnigia monnigi

Pithecostrongylus alatus

Macielia falsa



Trichskrjabima malayana



Pulchrostrongylus complexus

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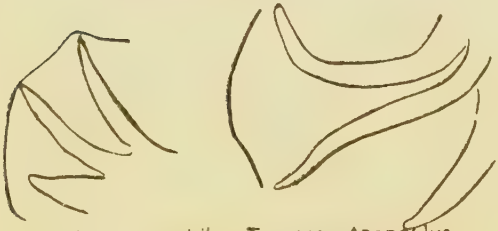
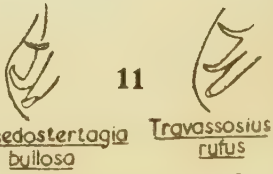


Nicollina sarcophili

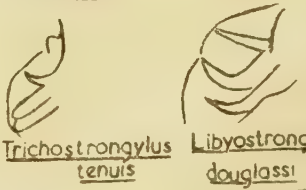
Travassostrongylus tertius



Psedostertagia bullosa

11

Travassosius rufus



Trichostrongylus tenuis

Libyostrongylus douglassi

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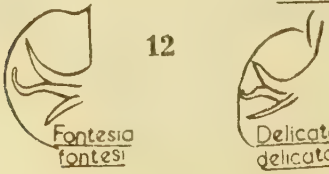
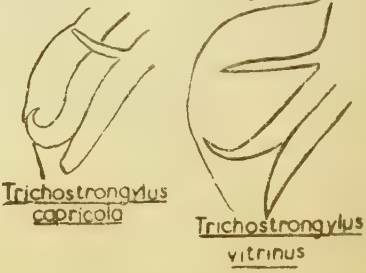


Fontesia fontesi

Delicata delicata

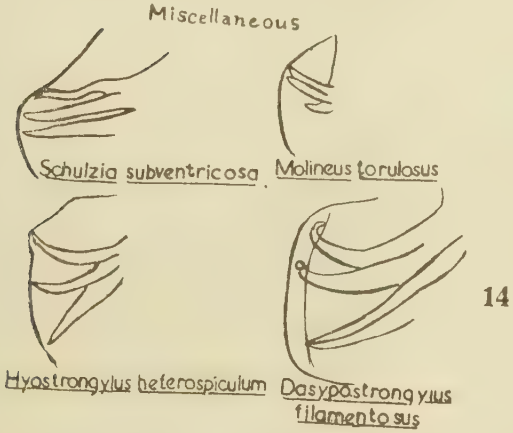
Amphibiophilus acanthocirratus

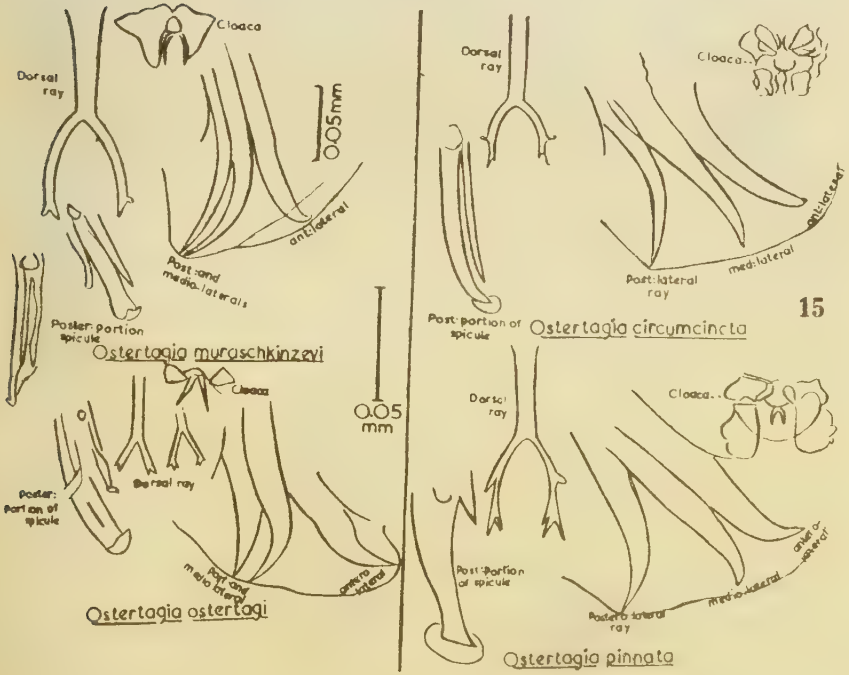
Oswaldocruzia mazzai



Trichostrongylus capricola

Trichostrongylus vitrinus


Miscellaneous
Schulzia subventricosa
Molineus torulosus
Hyostrongylus heterospiculum
Dasypostrongylus filamentosus
14


Cloaca
Dorsal ray
0.05mm
anti:lateral
Post: and media:laterals
Poster: portion spicule
Ostertagia muraschkinzevi
0.05 mm
Cloaca
Dorsal ray
Poster: portion of spicule
Post: and media: laterals
antero lateral
Ostertagia ostertagi
Dorsal ray
Cloaca
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Ostertagia circumcincta
15
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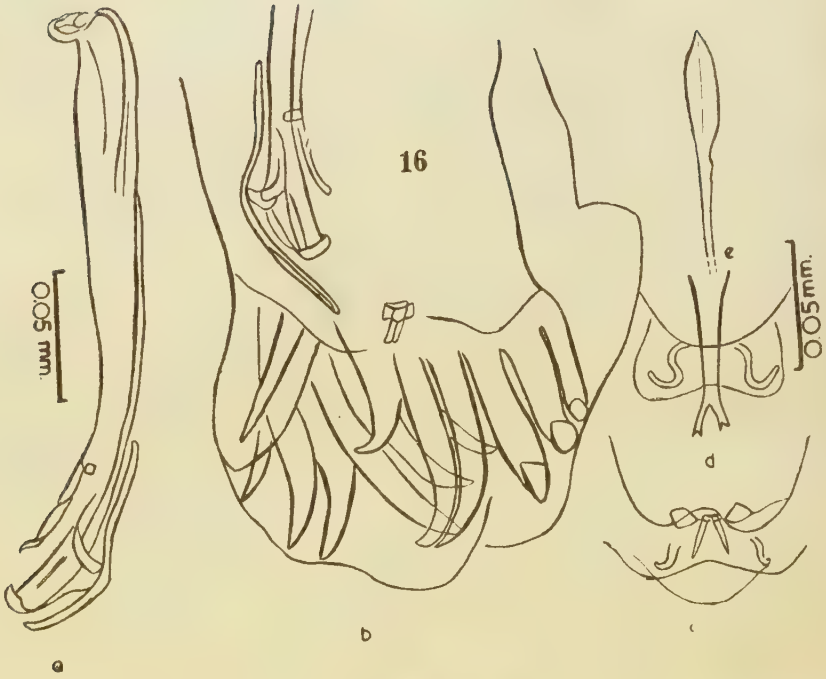
Cloaca
Post: portion of spicule
Postero lateral ray
Ostertagia pinnata



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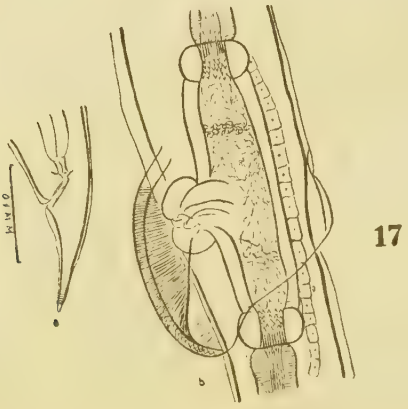

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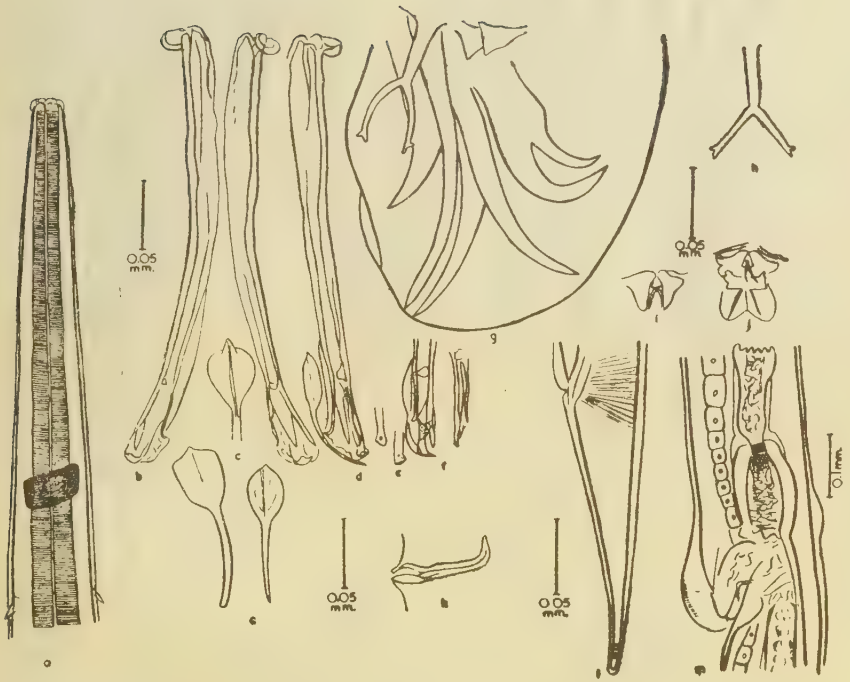

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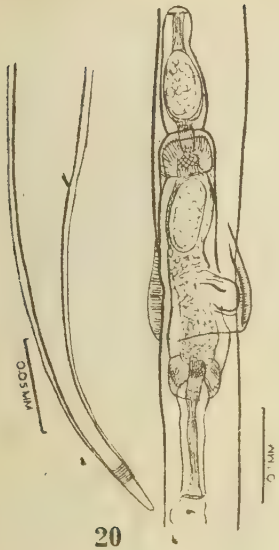

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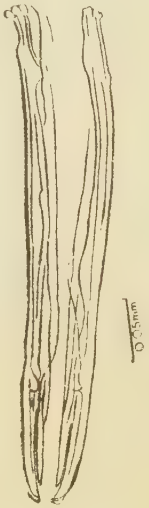

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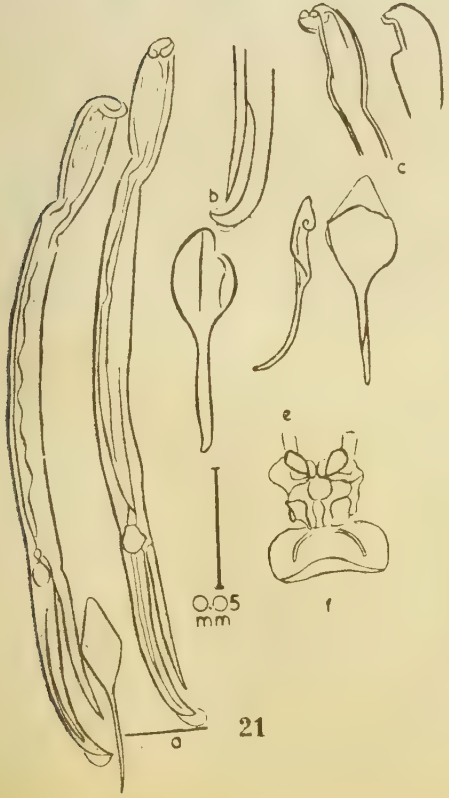

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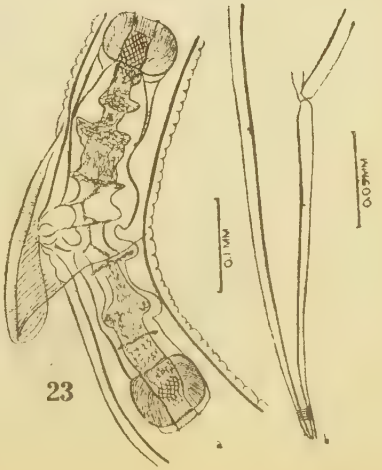

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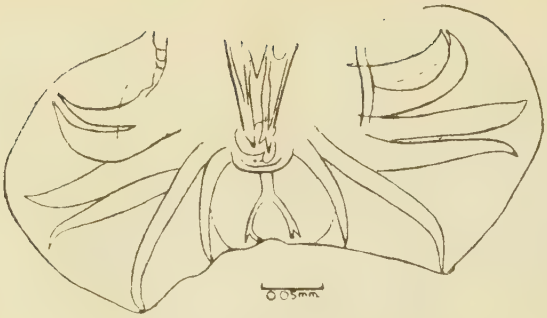

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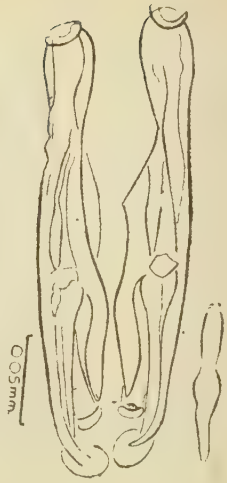

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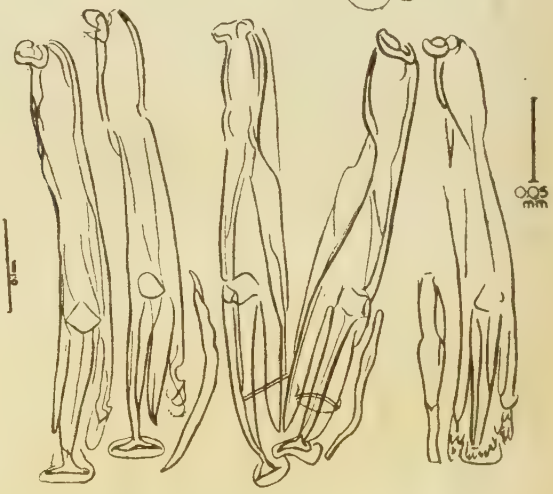

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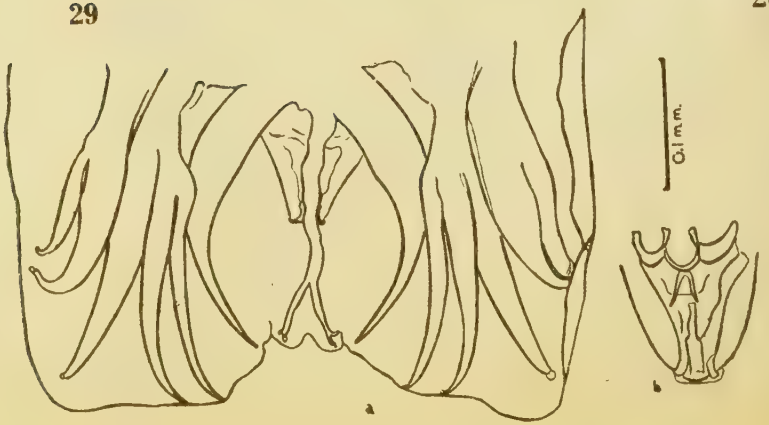

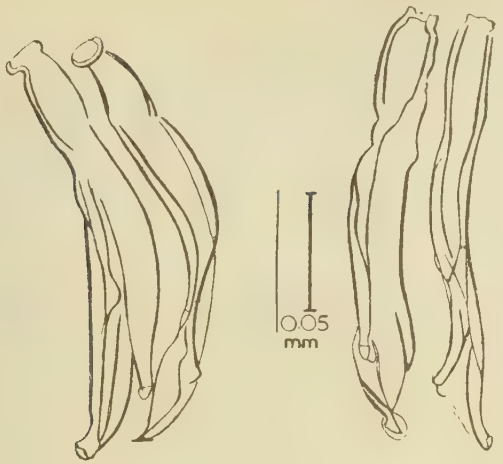

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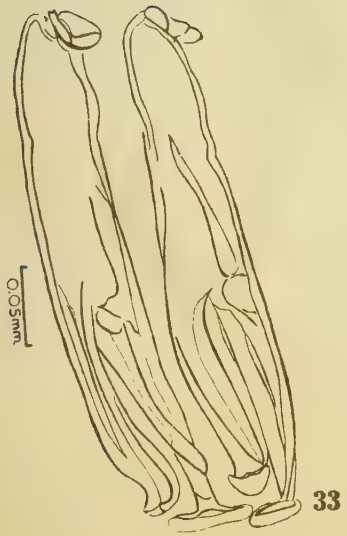

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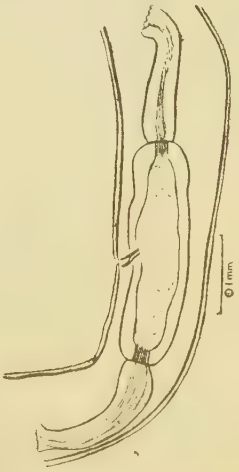

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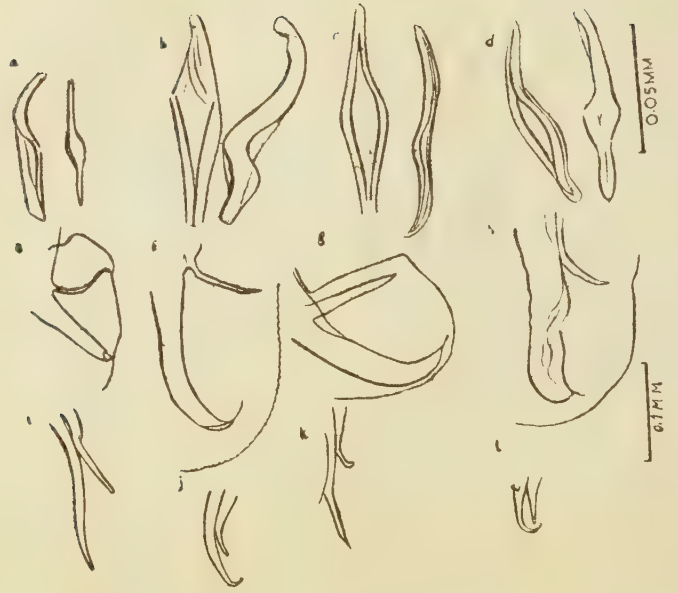

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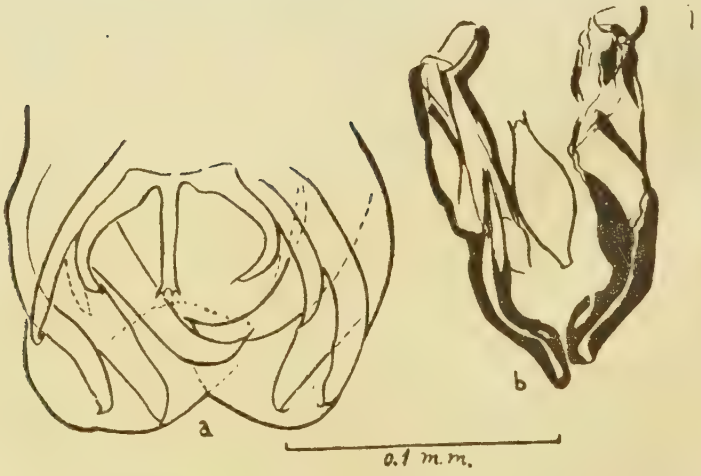

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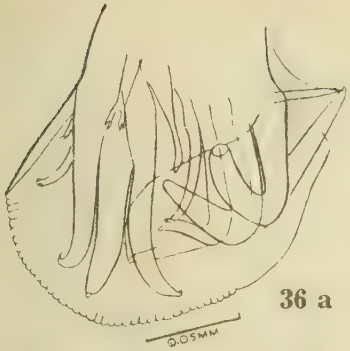

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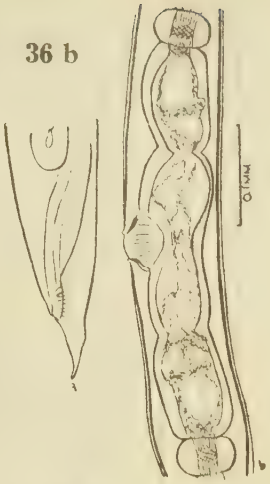

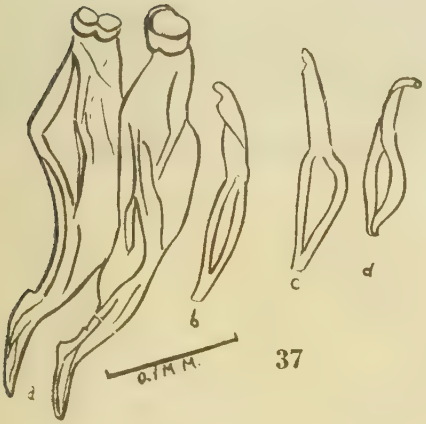

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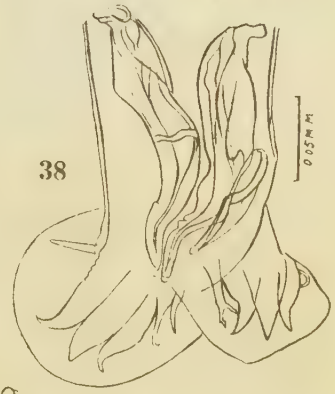

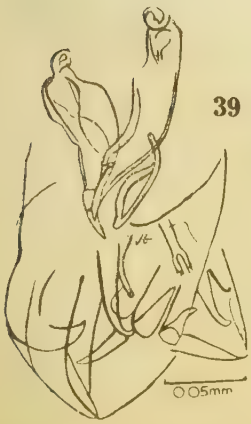

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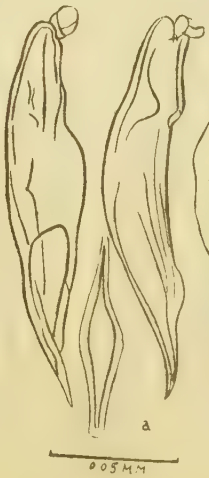

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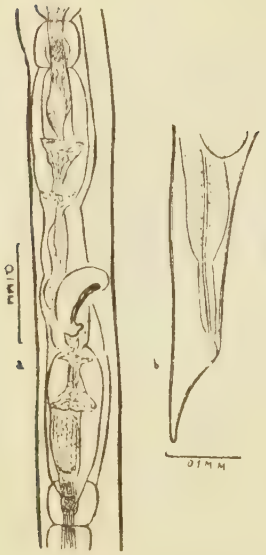

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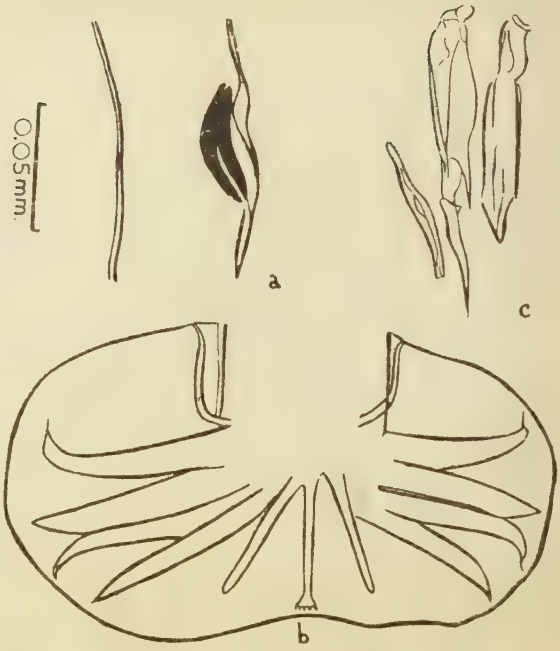

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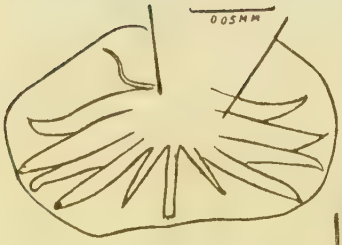

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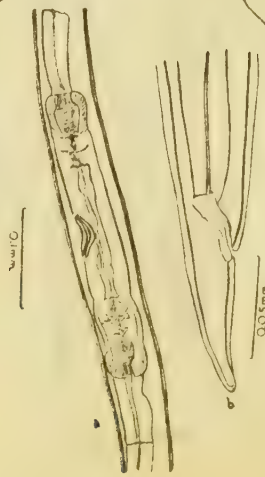

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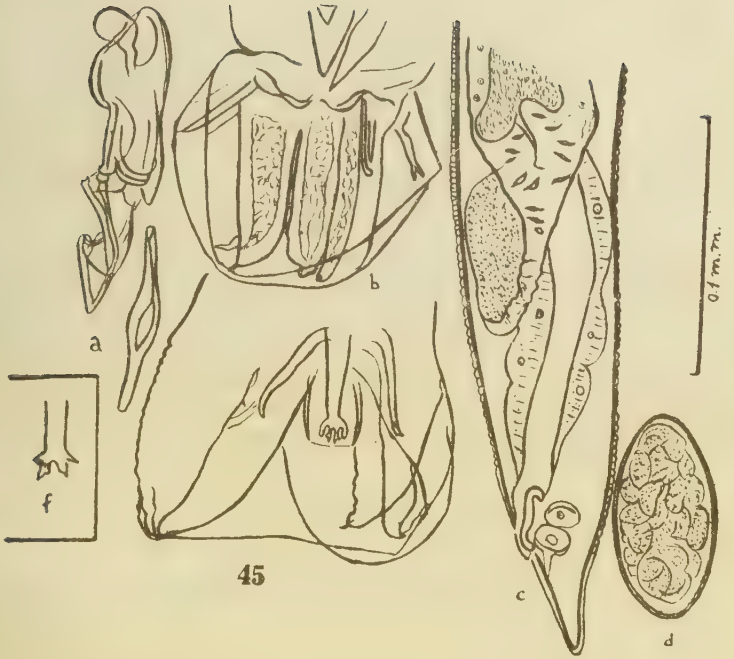

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Colletotrichum Capsici (Sydow) Butler and Bisby on Piper betle

Abdul Hafiz* Khursheed Akbar‡ and Murtaza Shariff‡

In January 1956, it was observed that the vines of *Piper betle* Linn. in an experimental plot at Manora Island, Karachi, Pakistan, were seriously attacked by a wilt-disease. On isolation two fungi belonging to the genera *Colletotrichum* and *Rhizoctonia* were obtained.

Available literature shows that no species of *Colletotrichum* has so far been recorded on *Piper betle* Linn., although the fungus has a wide host range. This has also been confirmed by the Director, Commonwealth Mycological Institute, Kew, who further states that so far he has not received specimens of this fungus from any other species of *Piper* even.

According to Mason this species (accession no. IMI. 62650) resembles *Colletotrichum capsici* (Sydow) Butler and Bisby. The measurements of the fungus recorded by the authors on Potato dextrose agar are : spores 20x3.8 μ ; *setae* 58-348 μ long, with an average of 145 μ, and *acervuli* 72-348 μ, with an average of 148.6 μ in diam. These measurements agree closely with those of *C. capsici* (Sydow) Butler and Bisby (Sacc : XXV : 196 : *Vermicularia capsici* Sydow ; *spores* 17-28x3-4 μ ; *setae* 70-145 μ long, and *pycnidia* 79-120 μ).

Therefore, the species under reference is referred to *Colletotrichum capsici* (Sydow) Butler and Bisby.

Pathogenicity tests on *Capsicum* sp. and other host plants are in progress.

The authors are highly indebted to Mr. E.W. Mason and the Director, Commonwealth Mycological Institute, Kew, England for their kind assistance in identification.

* Food and Agriculture Council, Pakistan, Karachi.
‡ Department of Plant Protection, Karachi.

Stereum ahmadi nov. sp.

(Basidiomycète : Théléphoracé)

JACQUES BOIDIN

Laboratoire de Botanique, Faculte des Sciences, Lyon, France.

Notre collègue Pakistanais Sultan Ahmad, nous a fait parvenir en october 1955, dès sa récolte, un spécimen indéterminé, d' allure très spéciale, qu'il nous a été possible de faire sporuler à Lyon, après réhumidification, et d'étudier frais. Il s'agit d'une espèce, nous semble-t'il, non décrite que nous sommes très heureux de dédier à notre collègue Sultan Ahmad.

✓ **Stereum ahmadi :** *Stereo frustulato* proximum propter plurima tabulata sua, crassitudinem (1-2.5 mm.), acanthophyses, sporas amyloideas, minores 4.8-6.5 x 3.2-3.75 μ), sed nonullis hyphis horizontalibus differt, unde margo paulum reflexa, rimis carentibus. Gloeocystidiis multis tunica interdum maxime incrassata atque intus ope sulfoaldehydum valde nigrescentibus ; hyphis fibulatis.-In ligno putrido (Pakistan).

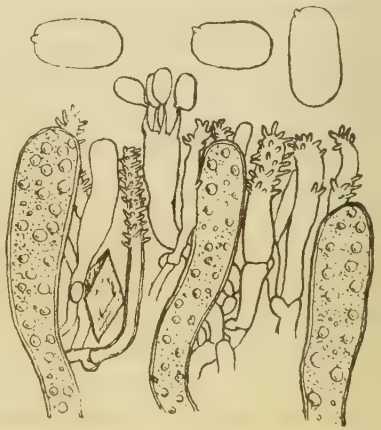
Débute par des disques à bords un peu soulevés puis forme une croûte épaisse (I á 2.5 mm.), dure, à surface irrégulièrement boursouflée, de couleur grise ((I) M 10 YR 5,5/2) marbré de zones plus claires (M 10 YR 7 à 8/2) ou plus rosées M 7, 5 YR 7/2) avec marge abrupte ou étroitement soulevée plus pâle. En séchant il devient plus cassant, gris sale marbré d'ocre rosé (M 8 á 9 YR 7,8/2,5) mais ne se montre aucunement fendillé. Dessous brun noirâtre mat.

Sur une coupe, on distingue nettement à l'oeil nu, ou mieux à la loupe, une zonation : la trame ou plutôt le contexte, couleur de liège (vers M 8,5 YR 6,8/4) est longitudinalement découpée par des lignes noires (8 à 10 pour 1.2 mm d'épaisseur) et séparé du substratum par une zone d' épaisseur irrégulière brun-noir. La postasse (KOH á 5%) assombrit fortement la coupe notamment au niveau des lignes sombres.

Au microscope une coupe perpendiculaire à la marge montre surtout des éléments verticaux disposés en hyménium superposés vers le centre, légèrement débordant vers l'extérieur coté marge, limités par des lignes horizontales brunes. Dans le Melzer ces lignes horizontales apparaissent presque noires. Tout à fait à la base s'étend une couche d'hyphes agglutinées brunes, et au dessus d'elle, plus ou moins développée une zone moins colorée d'orientation plutôt confuse qu'horizontale.

L'hyménium se compose : (*a*) de basides, bouclées, 22-32 x 4.5-5.5 μ, á 4 stérigmates longs de 3,-3.5 μ, nettement émergentes à maturité, (*b*) d' *acanthophyses* (bottle-brush paraphyses), 15-20-26 x 3-5 μ, couvertes sur la moitié ou le tiers supérieur par des appendices cylindriques, réguliers, (*c*) de quelques articles moins régulièrement hérissonés, (*d*) et de la terminaison de larges *gloeocystides* à paroi un peu épaissie, à contenu *reagissant violemment* en noir voilacé *avec le reactif sulfo-anisique* (2), et se colorant de brun-gris à bistre foncé avec de l'ácide sulfurique concentré.

Les Gloeocystides hyméniales sont subcylindriques ou légèrement claviformes, parfois étranglées ou au contraire un peu renflées en leur milieu, et toujours à terminaison largement obtuse, 50-60 x 8-11.5 μ. Les acanthophyses sont très nombreuses et constituent la plus part des éléments hyméniens ; elles ont une paroi un peu épaissie et les diverticules, réfringents comme la paroi, semblent pleins, c'est à dire constitués par des épaississements de la membrane. Ces acanthophyses ont des formes assez variables, subcylindriques, claviformes ou au contraire à sommet plus ou moins étroit et effilé ; elles peuvent montrer une ou plusieurs cloisons de retrait bombées, dans leur partie supérieure. Si certaines sont très différenciées, d'autres peu hérissonnées et seulement à leur extrémité semblent très proches des basides. Il est possible que dans une espèce pérennante, selon les conditions atmosphériques, les articles hyméniens nés des hyphes génératrices évoluent soit en basides soit en acanthophyses.



Basides, gleocystides et acanthophyses x 800. Spores x 2200.

Spores oblongues, fortement *amyloides*, 4.8-6.5 x 3.2-3.75 μ (mesures sur sporée, dans le Melzer).

Dans les parties sous-jacentes (anciens hyméniums!) on retrouve tousces éléments plus ou moins collapsés, de nombreuses spores enfouies à toutes les profondeurs, des articles hérissonnés, des gloeocystides sulfoaldéhydes positives à paroi souvent fort épaissie, et en outre des *hyphes generatrices* à paroi mince ou peu épaissie, aux cloisons fréquentes et bouclées (sans doute de manière constante), et des amas cristallins ou de gros cristaux losangiques, épars mais abondants dans toute l'épaisseur.

Les colorations des zones sombres (arrêts de végétation) est due à la présence de nécropigment brun dans les gloeocystides, à une coloration diffuse de toutes les membranes et à un dépôt aux allures souvent finement dendritiques recouvrant par plages les divers éléments. Ces dépôts sont plus ou moins attaqués par la potasse (KOH à 5%) qui se teinte de jaune, mais deviennent bleu-noir (comme hyperamyloides) dans le Melzer. Dans les zones d'arrêt de végétation, les gloeocystides peuvent se renfler en épaississant fortement leur membrane (paroi dépassant 4 μ d'épaisseur dans le Melzer), ce qui ne les empêche pas de donner naissance ensuite à leur sommet à un prolongement plus étroit à paroi plus mince. Ces gloeocystides traversent ainsi plusieurs strates et atteignent facilement 4 à 500 μ de longueur.

La couche subbasale d'hyphes non verticales est constituée d'hyphes génératrices et de gloeocystides (hyphes laticifères à contenu guttulé plus ou moins teinté, avec fréquents septums de retrait simples et bombés) que l'on retrouve dans la zone noire touchant le substratum ou formant la croûte, où elles sont seulement agglutinées et très colorées (membrane comme contenu).

Après traitement alcalin, l'observation en contraste de phase (3) permet de constater la présence de boucles aux cloisons basales de tous les éléments hyméniens et aux septums des hyphes de la trame ; les boucles sont donc vraisemblablement constantes.

TYPE : LY 2063 ; legit S. Ahmad no. 13057, on decayed logs, Lun Bagla, PAKISTAN, 4-9-1955.

Cette espéce se rapproche beaucoup par sa microscopie de *Stereum frustulatum* (Pers. ex Fr.) Fckl. Elles ont en commun la grande épaisseur avec structure étagée, l'absence ou le faible développement d'hyphes horizontales, la présence de longs éléments subcylindriques à paroi plus ou moins épaissie, d'acanthophyses, et de spores amyloides (4). Elles diffèrent par l'aspect, *St. ahmadi* n'étant pas du tout frustuleux, par les boucles qui absentes chez *St. frustulatum* (4) sont très fréquentes chez notre *Stereum*, et par un caractère quantitatif : alors que la trame de *St. ahmadi* est surtout constituée de gloeocystides (ou hyphes laticifères à paroi épaisse), celles-ci sont rares dans *St. frustulatum* et les acanthophyses profondes et brunies sont par suite beaucoup plus évidentes chez ce dernier.

On peut hésiter à le placer dans les *Stereum*, comme l'on a toujours fait cependant pour *St. frustulatum*, ou au contraire dans les *Aleurodiscus*. S'il existe dans les deux genres des espèces à spores amyloides, nous ne connaissons, à ce jour, que certains *Aleurodiscus* pour posséder des gloeo-

cystides sulfo-aldéhydes positives. Mais personne n'a jamais essayé cette réaction sur des récoltes fraîches des *Stereum* du groupe *subpileatum* (comme *St. sepium, insigne, annosum* etc...). Contrairement aux *Aleurodiscus* les éléments hyméniens sont de petite taille, les spores notamment, ce qui les rapprocherait par contre de divers *Gloeocystidiellum.* Des *Stereum,* il se distigue avant tout par l'absence ou le faible développement d'une strate d'hyphes horizontales.

C'est sa parenté indiscutable avec *St. frustulatum* et *annosum,* ce dernier ayant déjà davantage un port de *Stereum,* qui nous incite à le placer dans le genre *Stereum,* étant bien entendu qu'il faudra sans doute se résigner un jour à séparer les *Stereum* à acanthophyses des *Stereum* vrais comme *Stereum hirsutum* ou *sanguinolentum.*

En terminant, qu'il nous soit permis de dire notre reconnaissance à Sultan Ahmad pour la confiance qu'il nous a témoigné et pour son amicale collaboration, ainsi qu'à H. Romagnesi qui a bien voulu une fois encore nous faire profiter de sa connaissance de la langue latine.

TRAVAUX CITES

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(2) BOIDIN, J., 1950. Les réactifs sulfo-aldéhydiques : leur intérêt pour la détermination et la classification des Thélephoracées. (Basidiomycètes). Bull. Soc. Natural. Oyonnax, **5** : 72-79. La formule que nous préconisons actuellement est : SO_4H_2 : 5 cc., eau : 1.5 cc., aldéhyde : 0.25 cc.

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[Received for publication on May 1, 1956.]

A Bibliography of the Flowering Plants of West Pakistan and Kashmir.

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As there is no bibliography of the literature which is useful to botanists working in West Pakistan which is easily available, the following has been compiled. It is not exhaustive but it contains those works most likely to be useful. Unfortunately there is no first class library where the majority of these books and articles can be found. Probably the best are the libraries of the Forest Research Institute in Abbotabad, the Panjab University Library and that of the Lyallpur Agricultural College. Most of the references are unfortunately to books and articles long out of print or to articles in the proceedings of such societies as the Indian Botanical Society, the Linnaean Society, the Asiatic Society of Bengal and the Bombay Natural History Society. Many of the most useful books and articles are in the Library of Gordon College and I have checked these references but for the sake of greater usefulness, I have included a number of references gleaned from my notebooks and especially from the very fine bibliographies to be found in the Journal of the Bombay Natural History Society. The first is by the late Ethelbert Blatter and is to be found in Vol. 29 and was published in 1911. It is very complete and lists 1508 books and articles on the plants of the old British Indian Empire. The second brings the list almost up-to-date and was compiled by H. Santapau, S. J. It is in two parts, in the 1950 and 1951 volumes of the same journal. Another valuable bibliography is that of Merrill and Walker. For the sake of brevity, I am using the abbreviations for the journals cited most frequently. No attempt has been made to cite any references in the Pflanzenreich or Engler and Prantl's Pflanzenfamilien.

ABBREVIATIONS

JBNHS	Journal of the Bombay Natural History Society
JIB	Journal of the Indian Botanical Society
JLS	Journal of the Linnaean Society, London
TLS	Transactions of the same society
RBSI	Records of the Botanical Survey of India

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* Jacquemont who died before he could return to France is important in being the first botanist to collect in Kashmir proper. Moorcroft collected in Ladak a decade earlier.

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The postcranial skeleton of *Uromastix hardwickii* Gray

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The skull of the common lizard, *Uromastix hardwickii,* has been described in detail previously (Islam, 1955). The present paper deals with its postcranial skeleton, i. e., the vertebral column, ribs, sternum, girdles and limbs. It is based on a study of over 3 dozen skeletons, some dry, others cleared by the alizarin method. Fresh or formalin-preserved specimens were used for studying the insertion of muscles on the long bones.

THE VERTEBRAL COLUMN

Like other parts of the endoskeleton, the vertebral column is fully ossified, and the centra of the vertebrae have replaced the notochord completely. The vertebral column may be divided completely into four regions viz., cervical, thoracico-lumbar (dorsal), sacral and caudal.

I. CERVICAL REGION. The cervical or presternal region consists of the eight vertebrae immediately behind the skull. The last 4 or 5 cervical vertebrae bear ribs which, however, do not articulate with the sternum. In possessing 8 cervical vertebrae, *Uromastix hardwickii* agrees with *Sphenodon* (Howes & Swinnerton, 1901) and the majority of lizards (El-Toubi, 1947), but differs from the allied species, *Uromastix aegyptia (=U. spinipes)* which has only seven (Gadow, 1933). Beddard (1905) defines cervical vertebrae as those having no ribs at all. Thus, he finds that in *Chlamydosaurus* there are 4 cervical vertebrae and the total number of the presacral vertebrae is 24. In *Uromastix hardwickii,* according to this definition, there are only 2 cervical vertebrae (or 3, if one does not regard the nodules of calcified cartilage on the third vertebra as ribs), though the total number of presacral vertebrae is 24 as in *Chlamydosaurus* and a large number of other lizards. Beddard's criterion is not very satisfactory because cervical ribs are a common occurrence in many groups of vertebrates.

The axis and the three succeeding vertebrae have a small, ventrally projecting process, the hypapophysis, borne on the posterior ventral side of the centrum, almost at the junction of the two centra. The odontoid process of the axis has a hypapophysis of its own. The hypapophysis is not fused with the centrum but has a ligamentous joint with it.

The first two cervical vertebrae, viz., the atlas and the axis (epistropheus) are modified in the usual way of the Amniota.

The atlas (Fig. I, **1** & **2**). This is the first cervical vertebra and differs from others in being permanently temnospondylous, i. e. having its component parts separate. As in all Amniota, it is ring-shaped and consists of 3 pieces, one ventromedian piece representing the hypocentrum, and two dorsolateral pieces, the neurapophyses. The pleurocentrum of the atlas becomes attached to the centrum of the axis to form its odontoid process (odontoideum or dens epistrophei). The suture between the odontoideum and the centrum of the axis can be seen very clearly in a dried vertebra or in one cleared in oil. The cavity enclosed by the 3 pieces of the atlas is divided by a horizontal ligament into the dorsal neural cavity for the spinal cord, and the ventral cavity into which the odontoid process of the axis fits.

The ventromedian piece or hypocentrum is a small triangular bone with its apex pointing ventrally and the other two angles rounded off. It shows a facet on both anterior and posterior aspects : for articulation anteriorly with the occipital condyle and posteriorly with the anteroventral surface of the odontoideum. On each side the facet is continued on to the neurapophyses. There is no hypapophysis attached to the atlas—the hypapophysis of this vertebra being attached to its pleurocentrum (odontoideum).

The neurapophyses are curved pieces attached to the dorsolateral ends of the hypocentrum. In the side view each neurapophysis is seen as a dumbbell-shaped bone with a prominent postzygapophysis just above the constriction. Dorsally the two neurapophyses are separate, though closely approximated. The space between the two is filled with a membrane or occasionally by a cartilaginous prolongation of the neural spine of the axis. In the constricted region of the two neurapophyses stretches the ligament separating the neural canal from the space for the odontoideum. The postzygapophyses are small oval areas on the posterior face of the neurapophyses, and face downwards and somewhat inwards.

The three components of the atlas are joined with each other by means of cartilage which forms an almost complete sheath round the hypocentrum. This connexion through cartilage is not uncommon in lizards, though in many cases, e. g. *Scincus scincus* (El-Toubi, 1938) the joint is sutural, and in still others, e. g. *Hemidactylus flaviviridis* (Mahendra, 1950) the three pieces are connected together by ligament. *Varanus monitor* also agrees with *Scincus* in this respect.

There is no pro-atlas.

The axis (epistropheus) (Fig. I, **3**). The second cervical vertebra is like the remaining cervical vertebrae : its neurapophyses fuse in the mid-dorsal line to form a prominent, longitudinally falttened, plate-like neural spine or processus spinosus. The centrum is also well-developed and has a strong posterior convexity. In the anterior view the centrum, with the odontoid process and hypapophysis attached to it, appears saddle-shaped, but when these processes are removed, the centrum is seen to be typically procoelous. The prezygapophyses are small, flattened articulating surfaces at the base of the neural arch. They face upwards and outwards and not upwards and inwards as a typical prezygapophysis would. The postzygapophyses are well-developed and typical, i. e., they face downwards and outwards.

The odontoid process (dens epistrophei) which represents the pleurocentrum of the atlas, is a small triangular bony nodule suturally attached by its base to the centrum of the axis. Its upper surface is more or less flat and rises up making a small angle with the horizontal axis. The lower surface is very slightly concave anteroposteriorly, but convex from side to side. The odontoideus is a single bone and there is no indication that its tip has ossified separately. According to Goodrich (1930) the pleurocentrum of the segment giving rise to the atlas may be expected to fuse with the odontoid process.

The hypapophysis of the odontoideum is a bony nodule somewhat larger than the latter, and is attached just below it to the anteroventral face of the centrum. Ventrally, it has a small conical process. Like the odontoid process, the hypapophysis is attached to the centrum suturally.

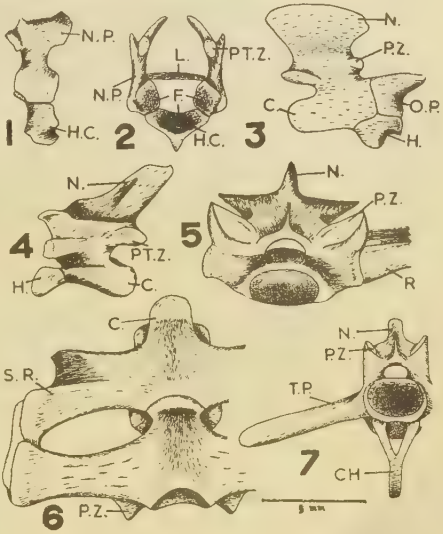

Fig. I. VERTEBRAE. **1**, Atlas, side view ; **2**, Atlas, posterior view ; **3**, Axis, side view ; **4**, typical cervical, side view ; **5**, typical dorsal, anterior view ; **6**, sacrals, ventral view; **7**, caudal, anterior view.

C., centrum ; *CH.*, chevron bone ; *F.*, facet for odontoid process ; *H.*, hypapophysis ; *H.C.*, hypocentrum ; *L.*, ligament ; *N.*, neural spine ; *N.P.*, neurapophysis ; *O.P.*, odontoid process ; *PT.Z.*, postzygapophysis ; *P.Z.*, prezygapophysis ; *R.*, rib ; *S.R.*, sacral rib ; *T.P.*, transverse process.

The axis has a hypapophysis of its own also. This hypapophysis is

attached on the ventral side at the junction of the centra of the axis and the third vertebra. It is not fused with the centra but connected only through ligament.

The axis bears no ribs.

Posterior cervical vertebrae. The third cervical vertebra (Fig. I, **4**) is really typical of all the presacral vertebrae behind the axis. It is very pronouncedly procoelous with large typical zygapophyses and a long backwardly directed neural spine. The neurapophyses are completely fused with the centrum, and unlike *Scincus scincus* (El-Toubi, 1938) and some other lizards, there is no suture at their junction. There is a deep notch between the postzygapophysis and the convex end of the centrum ; consequently, a large intervertebral foramen is enclosed on each side between adjacent vertebrae for the passage of the spinal nerve. Below and at the base of prezygapophysis, i. e. at the junction of the centrum and the neurapophysis, there is, in the cervical and dorsal vertebrae, a facet for the rib. The ribs of the third vertebra are represented by minute nodules of calcified cartilage. Other cervical and all dorsal vertebrae possess prominent, single-headed, bony ribs movably articulated with the vertebra. There are no subcentral foramina.

From before backwards, the presacral vertebrae tend to acquire a larger centrum and a shorter,more obliquely (backwardly) disposed, plate-like neural spine.

II. THORACICO-LUMBAR (DORSAL) REGION. The number of the dorsal vertebrae is usually 16, as also in many other members of the Agamidae, e.g. *Agama stellio* (El-Toubi, 1947). In one specimen of *Uromastix*, however, 17 dorsal vertebrae were counted. These vertebrae (Fig. I, **5**) are typical in structure.

III. SACRAL REGION. Like almost all modern reptiles, *Uromastix hardwickii* possesses two sacral vertebrae. The sacral vertebrae (Fig. I, **6**) are characterized by the possession of strong sacral ribs which are fused with the centrum and support the pelvic girdle. The sacral ribs are sometimes regarded as transverse processes (Moodie, 1907 ; Iyer, 1942 ; Mahendra, 1950). However, El-Toubi (1947) has found that in *Agama stellio* the rib of the last dorsal vertebra may fuse with the centrum to give the appearance of a transverse process. Separate sacral ribs are known to occur in many primitive (extinct) reptiles (Watson, 1918); and in many modern lizards they are known to ossify separately only to become fully fused with the centrum in the postembryonic condition. These pieces of evidence sug-

gest strongly that the stout lateral processes of the sacral vertebrae are best regarded as sacral ribs.

The rib of the anterior sacral vertebra has a swollen end which abuts against the ilium. The abutting surface is deeply concave, but the rim of the cup is dented on one side so that only a crescentic area, which is anterodorsal in the natural position, comes in actual contact with the ilium. The above-mentioned dent forms a part of the intervertebral foramen.

The rib of the second sacral vertebra is provided, on its posterior side, with a wing of thin bone, and thus appears much broader than that of the first. However, the tip of only the rib proper (i.e. the thicker part) articulates with the girdle. The ribs of the posterior sacral vertebra are situated at a slightly lower level than those of the anterior. This feature has also been recorded in *Calotes versicolor* (Iyer, 1942).

Apart from the characteristic ribs, the sacral vertebrae agree in all respects with a typical vertebra.

IV. CAUDAL REGION. The usual number of caudal vertebrae is 33, but 31 or 32 vertebrae have also been counted in apparently complete specimens. A considerable reduction in the number of caudal vertebrae may take place by injury. Specimens with only 17 or 18 caudal vertebrae have also been met with. The characteristic features of the caudal vertebrae are the transverse processes and chevron bones.

The anterior caudal vertebrae (Fig. I, **7**) resemble the sacral vertebrae in every respect except that transverse processes take the place of sacral ribs. The transverse processes are dorsoventrally flattened, long, pointed processes at right angles to the centrum, and share the general reduction in size from before backwards. However, they lose in width more rapidly than in length.

Posteriorly, the caudal vertebrae gradually lose in size and organization. The neural spine, zygapophyses, neural arch and transverse processes disappear in this order, thus reducing the vertebra to a small rod of bone. There is no indication of any uncalcified septa for autotomy.

The chevrons are Y-shaped bones representing the basiventrals. They are movably articulated on the ventral side between two vertebrae. The first three or four vertebrae are without chevron bones, the first chevron occuring usually at the junction of the third and fourth vertebrae, though in a few specimens it may be attached between the fourth and fifth verte-

brae. The chevrons are somewhat inclined backwards, the anterior ones more pronouncedly so than the posterior ones.

THE RIBS

With the exception of the caudal and the first three cervical, all vertebrae bear ribs. All ribs are movably articulated with the vertebra except (i) the sacral ribs, which have already been described in detail ; and (ii) the ribs of the third cervical vertebra, which are represented by nodules of calcified cartilage just below the prezygapophyses.

All ribs are single-headed and bony but usually having a very small piece of calcified cartilage at their tip. The cervical ribs gradually increase in length from the fourth cervical vertebra backwards. The sternal ribs, i.e. the ribs which articulate with the sternum, have two parts : a bony vertebral portion, and a sternal portion which is made of calcified cartilage and which is attached to the sternum. Tha vertebral part of all such ribs is almost equal in length, but the sternal portion elongates as the distance from the sternum increases. The bony part of these ribs is more curved than the last cervical rib. The dorsal ribs which do not reach the sternum may be described as "floating" or poststernal. The first seven poststernal ribs are of the same size as the vertebral part of a true rib, though much less curved. Behind these the ribs decrease gradually in size and are almost horizontally disposed.

All methods of study have failed to reveal any traces of uncinates and gastralia or abdominal ribs such as described in *Hemidactylus flaviviridis* (Mahendra, 1950).

THE STERNUM

The sternum (Fig. II) is a rhomboidal plate of calcified cartilage perforated by two oval fenestrae (fontanelles), one on either side of the median line. These fenestrae are closed by a membrane. The size of the fenestrae is variable. Attached to the posterior end of the sternum there are two long, curved bars of calcified cartilage representing the xiphisternum. The xiphisternal bars are much stouter than the sternal parts of the ribs also articulating with the sternum. Four pairs of ribs articulate with the sternum. Unlike *Calotes versicolor* (Iyer, 1942), *Agama stellio* (El-Toubi, 1947), *Iguana*, *Varanus*, and indeed most Reptilia (Goodrich, 1930), no rib is attached to the xiphisternum.

On the anterolateral sides of the rhomboidal sternum, in the thickness of the wall, there is a groove for the coracoid and epicoracoid. Attached to the ventral side of the sternal plate there is a cruciform membrane

bone called the episternum or interclavicle. The anterior tip of the longitudinal bar articulates with the clavicles ; the short, slender, horizontal limbs are free and lie below, i.e., ventral to, the epicoracoids, while the posterior longitudinal limb lies on the midventral side of the sternum. The posterior limb is the longest and stoutest, and extends almost to the posterior end of the sternum. Its exact posterior extent may, however, vary in different specimens.

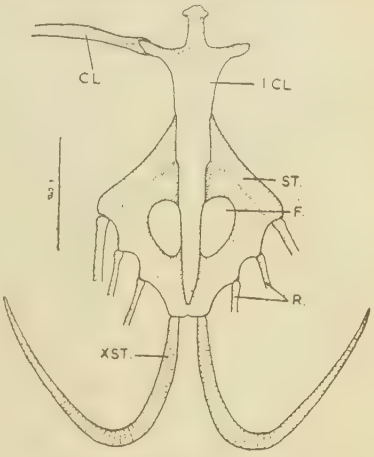

Fig. II. STERNUM. *CL.*, clavicle; *F.*, fenestra (fontanelle) ; *I.CL*,, interclavicle ; *R.*, rib, *ST.*, sternal plate ; *XST.*, xiphisternum.

THE PECTORAL GIRDLE

The pectoral girdle of *Uromastix hardwickii* (Fig. III) is built on the usual lacertilian plan. Each half of the girdle has a prominent glenoid facet to receive the head of the humerus. The region of the girdle dorsal to this facet is called the scapular region, that ventral to it is called the coracoid region. The scapular region consists of two elements, viz., the suprascapula which is formed partly of calcified cartilage and partly of bone, and the scapula, which is bony and forms almost one half of the glenoid facet. The coracoid region also comprises two elements, viz., the coracoid, which is bony and takes part in the formation of the glenoid facet, and the epicoracoid, which is formed of calcified cartilage and meets its fellow of the opposite side in the midventral line. Apart from these elements constituting the primary or endoskeletal pectoral girdle, there are two dermal elements, viz., the clavicle and the interclavicle or episternum.

Both scapula and coracoid have their anterior borders deeply indented so that three large fenestrae are formed, two in the coracoid region and one between the coracoid and scapular regions of the coraco-scapular plate. The former may be called the coracoid fenestrae, while the latter may be given the name of coraco-scapular fenestra. Similarly, the suprascapula has a large number of fenestrae along its dorsal edge. All the above-mentioned fenestrae are closed over by membrane.

The part of the anterior border of the suprascapula, to which the lateral end of the clavicle is attached, may be called the acromion region. In having the lateral (dorsal) end of the clavicle attached to the supra-

scapula *Uromastix hardwickii* agrees with *Scincus scincus* (El-Toubi, 1938), *Hemidactylus flaviviridis* (Mahendra, 1950), and many species of *Chamaesaura* (Essex, 1927), but differs from *Chlamydosaurus* (Beddard, 1905), *Calotes versicolor* (Iyer, 1942), and others.

Just dorsal to the acromion region, there is a short anteroventrally directed process which has not received any special name. A fairly wide triangular strip of the suprascapula, along its anterior border, is bony. However, there is no evidence to suggest that this bone is dermal in origin and therefore represents the cleithrum.

The *scapula* is a rectangular bone with concave anterior and posterior sides. The dorsal side abuts against the suprascapula, while the ventral side forms a part of the glenoid facet. A small projection from the anterior wall of the scapula forms a part of the ventral boundary of the coracoscapular fenestra. The scapula is not uniformly thick throughout : on its anterior side it presents a thinner edge than on its posterior side.

The *coracoid* is rather complicated in shape. Taking the glenoid facet as the point of reference, the coracoid may be described as a triangular bone from whose apex, which forms a part of the glenoid facet, two processes extend anteriorly. These processes have been formed due to the fenestration of the coracoid plate. The dorsal of these processes forms the lower boundary of the coracoscapular fenestra and may be called the procoracoid (precoracoid) process. The second, ventral process is rather narrower. In the angle between these two processes of the coracoid, just anterior to the glenoid facet, there is a small foramen in the coracoid. It is the coracoid foramen. The main body of the coracoid is quite wide and is very thick in the region of the glenoid fossa and also at its posterior ventral corner. Running along the base of the triangular coracoid, and completing the coracoid and coracoscapular fenestrae anteriorly, there is a strip of cartilage called the epicoracoid. The epicoracoid is widest in the anterior ventral corner which meets its fellow of the opposite side in the midventral line.

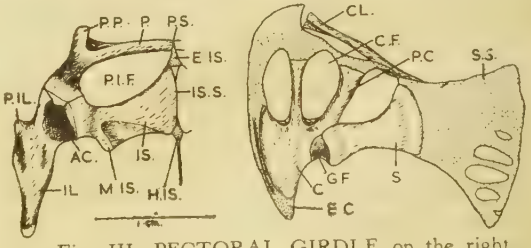

Fig. III. PECTORAL GIRDLE on the right, PELVIC GIRDLE on the left.

AC., acetablum ; *C.*, coracoid ; *C.F.*, coracoid fenestra ; *CL.*, clavicle ; *E.C.*, epicoracoid ; *E.IS.*, epischium ; *G.F.*, glenoid facet; *H. IS.*, hypoischium; *IL.*, ilium ; *IS.*, ischium ; *IS. S.*, ischiadic symphysis ; *M. IS.*, metischial process ; *P.*, pubis ; *P.C.*, procoracoid ; *P.I.F.*, pubo-ischiadic fenestra , *P.IL.*, preacetabular process of ilium ; *P.P.*, prepubic process ; *P.S.*, pubic symphysis ; *S.*, scapula ; *S.S.*, suprascapula.

Dorsally, this cartilage extends upto the junction between scapula and suprascapula.

The *clavicle* is a curved dermal bone whose dorsal end rests on the anterior border of the suprascapula. It runs for a short distance along the epicoracoid, and shows a deep groove along its posterior face. The ventral tip of the clavicle is concave and articulates with a small lateral projection from the anterior end of the interclavicle. The latter also is a membrane bone and has been described above in connexion with the sternum.

THE PELVIC GIRDLE

Each half of the pelvic girdle (Fig. III) is triradiate and consists of three bones united suturally with each other and together enclosing the acetabulum which is a rounded concavity for the head of the femur. The three bones are (i) the ilium, which is dorsal and backwardly directed, (ii) the ischium which is ventral and posterior and is the broadest of the three, and (iii) the pubis, which is ventral and anterior.

The *ilium* is a stout rod-shaped bone which is somewhat compressed in its anterior half. Anteriorly it expands to form the greater part of the acetabulum. Just dorsal to the acetabulum, the ilium shows a short blunt process called the preacetabular process. On the inner side, in the posterior rod-like region, there are facets for the sacral vertebrae. The facets for the two vertebrae are so arranged as to lie apparently one above the other.

The *ischium* is a thick, almost dumbbell-shaped bone, with a backwardly directed metischial process arising just below its dorsal end. The tip of the metischial process is connected with the ventral margin by a thin sheet of bone. The dorsal end, which meets the ilium and also forms the posterior ventral wall of the acetabulum, is thicker but shorter than the ventral end which is laterally compressed and expanded. The ischia of the two sides meet in the mid-ventral line at the ischiadic symphysis. Projecting backwards from the symphysis there is a rod-like bone, the hypoischium or os cloaca, which supports the ventral wall of the cloaca.

The *pubis* is a triradiate bone. Its dorsal limb, which is the broadest and perforated by the obturator foramen, articulates suturally with both ilium and ischium, and forms the posterior ventral wall of the acetabulum. It is compressed anteroposteriorly. The ventromedial limb of the pubis is the longest, and meets its fellow of the other side in the pubic symphysis. There is a very small nodule of cartilage in the region of the symphysis ;

this cartilage may be said to represent the epipubic which, in other forms, is a well-developed cartilage extending forwards beyond the pubic symphysis. Between the pubic and ischiadic symphyses there is a broad triangular piece of cartilage, the epischium, which, in older forms, gets completely or partially ossified. The ventrolateral limb of the pubis is formed by a large, downwardly directed process called the prepubic process or processus lateralis pubis (El-Toubi, 1947) or pectineal process (Mahendra, 1950). A thin sheet of bone runs between the prepubic process and the ventromedial limb of the pubis.

Between the ischium and pubis there is a large oval fenestra closed by membrane. Mesially, it is completed by the epischium. It is the ischiopubic or pubo-ischiadic fenestra.

THE FORE-LIMB

The fore-limb (Fig. IV) is pentadactyle and possesses the usual parts, viz., the humerus, radius and ulna, carpus, metacarpus and phalanges.

The humerus (Fig. IV, **1** & **3**). It is a short flattened bone, narrow in the middle but considerably expanded at its extremities. The extremities are not flattened in the same plane but make an angle of about 45° with each other. This twist is apparently a primitive feature, being exhibited by most primitive reptiles (Romer, 1949). At its proximal end there is a smooth, elongate oval thickening, the head, which articulates with the glenoid facet of the pectoral girdle. The oval shape of the head is also primitive : the advanced forms having a distinct spherical head. On the preaxial side of the head, there is a very stout vertically directed ridge or crest, called the pectoral crest, for the insertion of the chest muscle or *pectoralis*. At the base of the crest, i.e. nearer the head, there is a small tuberosity, called the deltoid crest, for the insertion of a muscle of that name. On the postaxial side of the head, and just adjacent to it, there is a small tuberosity for the insertion of the *latissimus dorsi*.

As in most primitive reptiles, the shaft, i.e. the region between the two expanded extremities, is very short. Distally, the humerus bears two rounded condyles on the under surface. The large round condyle on the preaxial side is the radial condyle or capitellum for articulation with the radius. Adjacent to it, almost in the middle of the distal end of the humerus, there is another condyle called the trochlea or ulnar condyle. On the postaxial side, next to the trochlea, there is a raised area, the entepicondyle. A smaller ectepicondyle is present at the base of the radial condyle. There is no entepicondylar foramen, but a minute ectepi-

condylar foramen (called *ectepiforamen* by Mahendra, 1950) is present just above the ectepicondyle. This foramen is found also in *Sphenodon* and in many lizards and turtles (Romer, 1949) and is said to be formed by the fusion of the supinate process (found in many primitive reptiles) with the ectepicondyle.

The radius (Fig. IV, **3**). The radius is a slender columnar bone articulating proximally with the radial condyle of the humerus and distally with the carpals. It lies parallel to the ulna, occupying the preaxial side of the fore-arm. The head of the radius is less expanded than that of the ulna, and is without any processes. The distal end is as poorly expanded as the head.

The ulna (Fig. IV, **3**). The ulna is a slender bone similar to the radius, but having a thicker head. On the postaxial side, the head of the ulna is produced backwards (upwards) into a short blunt process, the olecranon. The head with the olecranon process forms a concavity, the sigmoid fossa, for articulation with the ulnar condyle (trochlea) of the humerus. The olecranon seems to have been ossified separately and is joined to the ulna suturally. It serves for the attachment of the extensor muscle of the upper arm. Proximal to the olecranon there is a separate small ossification, the patella ulnaris or brachial patella, between the ulna and the humerus. This ossification has been recorded in many lizards.

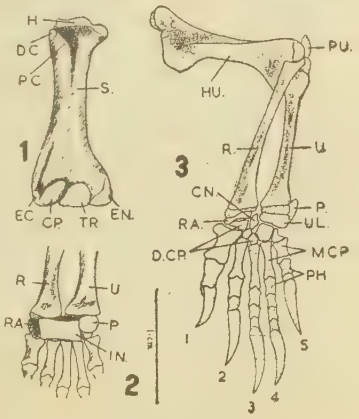

Fig. IV. BONES OF THE FORE-LIMB. **1.** Humerus; **2,** Carpus, palmar view; **3,** Entire fore-limb.

CN., centrale; *CP.*, capitellum or radial condyle; *D.C.*, deltoid crest; *D.CP.*, distal carpals; *EC.*, ectepicondyle; *EN.*, entepicondyle; *H.*, head; *HU.*, humerus; *IN.*, intermedium?; *M.CP.*, metacarpals; *P.*, pisiform; *P.C.*, pectoral crest; *PH.*, phalanges; *P.U.*, patella ulnaris; *R.*, radius; *RA.*, radiale; *S.*, shaft; *TR.*, trochlea or ulnar condyle; *U.*, ulna; *UL.*, ulnare; *1-5*, the five digtis.

The carpus (Fig. IV, **2** & **3**). There are 9 carpal bones, eight of which are arranged in three rows. There is a proximal row comprising 4 carpalia, viz., the radiale, the ulnare and the pisiform; a middle row including only a single centrale; and a distal row consisting of 5 small carpalia. The ninth carpal bone, probably a new ossification, lies on the underside of the wrist.

The radiale and ulnare articulate respectively with the radius and ulna. The ulnare is shaped like a disc which is deeply concave on its proximal side. The radiale is irregular and elongated transversely to the

long axis of the limb. The pisiform is an irregular bone attached on the lower (palmar) side of the ulnare. The size of the ulnare varies in different specimens. The above-mentioned ninth carpal bone is the largest element in the carpus. It is a flat triangular bone extending, on the palmar side, between the pisiform and the radiale. The centrale and the distal carpals are all small irregular nodules of bone. The fourth distal carpal is the largest of the five, the fifth comes next in size, while the other three are very small. The distal carpals articulate with the five metacarpals.

The metacarpus and phalanges (Fig. IV, **3**). The metacarpals are five in number, each articulating with the corresponding distal carpal bone. The third metacarpal is the longest, the fourth and second come next in order of size, while the first and the fifth are almost equal in length and shortest of all. The first metacarpal is the stoutest. The metacarpals are followed by phalanges which are arranged according to the primitive formula, i.e., 2, 3, 4, 5, 3. All digits end in a claw.

THE HIND-LIMB

The hind-limb (Fig. V) is typical in structure and consists of femur, tibia and fibula, tarsus, metatarsus and phalanges.

The femur. The femur is a cylindrical bone slightly expanded at its ends. It is considerably longer than the humerus. Proximally it bears a prominent ovoid head which articulates with the acetabulum. On the ventral side of the bone, slightly to the preaxial side and somewhat distally to the head, there is a very strong internal trochanter for the attachment of muscles. This trochanter is preaxial in almost all reptiles (Romer, 1949). Since in the shank the preaxial bone is the tibia, the inner trochanter of the femur may also be called the tibial trochanter, but there is no basis for El-Toubi's (1938) view that in all Squamata the large trochanter near the head is the fibular trochanter. There is no adductor crest on the shaft of the femur, nor is there any noticeable fourth trochanter. The distal end of the femur is pulley-shaped : the preaxial (inner) rounded condyle, which is somewhat smaller than the other, is meant for the tibia, while the large, postaxial, rounded surface is for the fibula. A shallow groove separates the two surfaces dorsally, while on the ventral side there is a deeper groove near the distal end of the bone. Strong tendons are attached in, and to the sides of, this groove, as also on the lateral surfaces of the tibial and fibular condyles.

The tibia. The tibia is the preaxial element in the shank or lower leg, and is much stouter than the fibula. It is slightly curved and is ex-

panded as well as flattened at both ends. The upper end is more expanded but less flattened, and articulates with almost entire under surface of the distal end of the femur.

The head of the tibia shows a smooth, round protuberance on its fibular side. This protuberance moves in the groove between the two condyles on the femur. The cnemial crest, so prominent in other vertebrates (e.g. *Varanus*), is not noticeable. Between the tibia and the femur there are one or two minute ossifications best seen in alizarin preparations. These ossifications may be compared to patella tibialis. The distal end of the tibia presents a smooth surface for articulation with the tarsus. The epiphyses of the bone do not fuse with the shaft, but are easily separated when the bone is heated in a dilute KOH solution.

The fibula. The fibula is the postaxial bone in the shank. It is a delicate bone, slightly longer than the tibia. It articulates proximally with the femur and distally with the tarsus. Its ends are slightly expanded. Proximally the head of the tibia touches the fibula, but distally the two are separate.

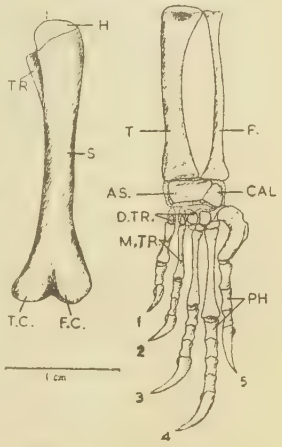

Fig. V. HIND-LIMB, *femur* on the left, *shank* and *pes* on the right.

AS., astragalus; *CAL.*, calcaneum; *D.TR.* distal tarsals; *F.*, fibula; *F.C.*, fibular condyle; *H.*, head; *M.TR* metatarsals; *PH.*, phalanges; *S.*, shaft; *T.*, tibia; *T.C.*, tibial condyle; *TR.*, internal trochanter; *1-5*, the five digits.

The tarsus. Like many primitive reptiles, the tarsus of *Uromastix hardwickii* is rather poorly ossified. The distal tarsals and the two small elements associated with the proximal row, consist of pieces of cartilage with only a part of each ossified in the adult. The tarsal bones are arranged in two rows. In the proximal row there are two tarsals. This is the usual condition in reptiles (Romer, 1949), though in many cases, e.g. *Agama stellio* (El-Toubi, 1947), *Calotes versicolor* (Iyer, 1942) and others, there may be a single large bony element in the proximal row. The exact homology of the two proximal tarsals has been the subject of much speculation, but most present-day workers on reptilian tarsus have accepted Broom's (1921) view that the two proximal tarsals represent the intermedium (astragalus) and fibulare (calcaneum), while the tibiale has been lost. However, the view that the tibiale has fused with the intermedium, is still held by many. The persistence of this view is no doubt due to the situation of the larger element (astragalus) which articulates both with

fibula and tibia. Some authors, e.g. El-Toubi (1938), assume that even centrale has fused with the proximal row of tarsals. Such assertions, however, are not justified without a study of the development of these elements in the animal concerned.

The astragalus is a large irregular bone articulating with the distal ends of both tibia and fibula. The calcaneum is a smaller element articulating with the distal end of fibula alone. There is no aperture between astragalus and calcaneum. In addition to these two usual elements there are, in many specimens, two small ossifications in this row. One ossification lies on the preaxial side of the astragalus and may possibly be the first (preaxial) distal tarsal. The other small ossification lies on the distal side at the junction of astragalus and calcaneum. It may be regarded as the centrale. These two minute ossifications vary in size in different specimens. In *Broomia perplexa* also, there is a small preaxial ossification in a large cartilage which, however, articulates with the tibia and is best regarded as the tibiale (Broom, 1921). In *Uromastix hardwickii*, however, the preaxial cartilage, or its ossification, does not articulate with the tibia and cannot, therefore, be homologized with the one in *Broomia perplexa*.

Apart from the inconstant centrale mentioned above, there are no ossifications or even cartilages which could be given that name. This is in keeping with the findings of Broom (1921) for the modern diapsid reptiles.

In the distal row there are only two tarsals, the smaller one being preaxial and articulating with the second and third metatarsals, while the large postaxial one articulating with the third, fourth and fifth metatarsals. Proximally, the large distal tarsal articulates between the astragalus and calcaneum. The fifth metatarsal, which is a curved, hook-like bone, is sometimes regarded as the fifth metatarsal and a distal tarsal combined (Mahendra, 1950).

The metatarsus and phalanges. There are five digits, each with its metatarsal bone. The first metatarsal is short but stout, the next three are long and delicate. The third and fourth metatarsals are much longer than the second. The fifth metatarsal (or metatarsal plus tarsal) is short, curved, flattened, and rather complicated in shape. This shape of the fifth metatarsal is come across in many lizards as well as in *Sphenodon*, and is sometimes regarded as having a phylogenetic significance. Its proximal end is very much expanded and articulates with the larger distal tarsal. Below (distal to) this broad head, the bone is narrower and somewhat twisted. On its outer side this bone bears a conspicuous tuberosity.

The pes of *Uromastix hardwickii* shows the primitive phalangial formula, i.e., 2,3,4,5,4. All digits are provided with prominent claws.

SUMMARY

1. The vertebral column of *Uromastix hardwickii* is well-ossified. There are 8 cervical, 16 dorsal, 2 sacral and about 33 caudal vertebrae. *Uromastix* agrees with most other lizards in having 24 presacral and 2 sacral vertebrae.

2. In the atlas the neurapophyses are connected with the hypocentrum through cartilage.

3. Neurocentral sutures are not visible in any vertebra.

4. In the caudal vertebrae there are no septa for autotomy.

5. Separate holocephalous ribs occur on all presacral vertebrae behind the axis. They are very much reduced on the last few dorsal vertebrae. The sacral ribs are fused with the centrum. There are no gastralia.

6. The general arrangement of the bones of the limbs is primitive.

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Residual Effects of Colchicine

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INTRODUCTION

During experiments to induce polyploidy in wheat by colchicine treatment certain interesting variations were observed. Several concentrations of colchicine solution were used, but the observations reported here were the result of treatment in 0. 2% aqueous solution of colchicine.

Seeds of *Triticum vulgare*, *T. durum*, *T. monococcum*, and of *Secale cereale* were first germinated aseptically and when the coleoptiles were about 5 mm. in length, the seedlings were immersed in 0. 2% aqueous solution of colchicine for a duration of 8 hours. After this interval the seedlings were transferred back to the germinating dishes, and when they were about 4"-5" in length they were transplanted in the soil where they continued to grow till maturity.

Soon after the colchicine treatment the root tips and the coleoptiles started swelling and in a few cases the swelling was so extensive that further growth seemed to have stopped and the seedlings died after a week or so. It has been observed that such seedlings generally secrete a dark yellowish precipitate-like substance which collects around the root tips. If this is removed, more of it collects soon, presumably after secretion from root tips. The coleoptiles generally remain colourless and do not develop the greenish tinge like those of the other or the normal seedlings. Unlike the coleoptiles of the untreated seedlings those of the treated seedlings become abnormally thick at the tips, and as such the leaves find it almost impossible to pierce through. The roots do not develop and the first or the primary root remains stunted so much so that all further growth seems to have come to a standstill, with the result that the seedling dies sooner or later.

The seedlings which continue growth do not show signs of such a drastic effect as described above. The root tips swell as well as the coleoptiles, but then the seedlings, although showing a reduced growth rate, continue to grow slowly and gain in length gradually. The adven-

titious roots develop but unlike the untreated seedlings, these are fewer on the treated seedlings. The coleoptiles remain short and the first leaf pierces through it when it is only half as long as that in the untreated seedlings. Oddly enough the coleoptile splits along two lines opposite to each other, unlike a side split (more or less of the follicle type) of the untreated seedlings. After transplantation into the soil the growth of the treated and the untreated seedlings is almost the same.

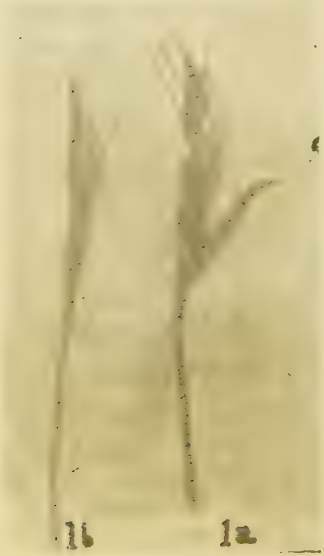
Measurements of stomata, leaves, stems etc., have shown that there is no appreciable polyploidizing effect of colchicine. Neither is there any change in the number of chromosomes. In the normal course of work such plants are discarded or, at any rate, are not kept under detailed and careful observation. The writer, however, selected and grew these plants for detailed observations in order to see if there was any delayed or residual effect of colchicine. It is the purpose of this paper to report preliminary observations on such effects ; detailed observations with statistical analysis will follow later.

Effects on ***Triticum vulgare*** *var.* ***pseudo-Hostianum,*** *Strain 9D.*

The treated plants, in comparison with the untreated plants, show many variations. The leaves are much darker green in colour and have the pubescence hair so developed that the aphids find the leaves unsuitable to thrive on. The leaves are of a thicker texture and have a tendency to fall early. The plants produce on the average about 20% less tillers and show an increased tendency to lodge. The internodes are thinner but the nodes do not show any appreciable difference, except that there is a prominent development of a brown ring on them. The ears are shorter and the glumes have a tendency to open prematurely, consequently the spikelets appear lax. In each ear the outer glume of the lowest spikelet is prominently developed into a small leaf-like structure resembling a flag. The seeds do not show any distinguishable difference, but there is a notable tendency towards sterility in the ear. The germination of the seeds is not effected. All these variations were found to be restricted only to the treated plants and were not observed in plants of the succeeding generation, (Fig. 1*a*).

Effects on ***Triticum durum*** *var.* ***melanopus,*** *Punjab Type 1.*

There is a general dwarfing effect on the whole plant, so much so that it is only about half as tall as the untreated ones. The leaves are smaller and the internodes much shorter in length. The tillering is completely suppressed. The ears are shorter, compact and the awns are white instead of being black. About 30% grains in each ear are thin, wrinkled,



EXPLANATION OF FIGURES

Fig. 1*a*. Ear of *Triticum vulgare* var. *pseudo-Hostianum*, strain 9D, showing the outer glume of the lowest spikelet developed into a leaf-like structure.

Fig. 1*b*. Ear of *Triticum monococcum*, var. *vulgare*, showing a small branch in the middle. The awns have been cut off so that the branch may be seen more distinctly.

Fig. 2. Ears of *Secale cereale*, showing the branched and bushy lower portion with bulbils developed prominently.

much smaller and weak. Healthy grains appear to be the same as those from the untreated plants. In the succeeding generation this general dwarfing effect disappears, and the plants, to all intents and purposes, look like the untreated ones.

Effects on ***Triticum monococcum*** *var.* ***vulgare***

The vegetative growth is very slow so that the shooting of the ear and anthesis are delayed by about ten days, as compared with the untreated plants. There is apparently no effect on the leaves and stem so far as external morphological characters are concerned, but the leaves of the treated plants show a susceptibility to rusts, i.e., *Puccinia graminis* and *P. triticina*. The rust pustules are large and extensive, and almost all the leaves on the plant are infected. The tillering capacity is reduced to 80% and the stems which otherwise are sturdy and strong, lodge rather easily. The ears are shorter and often show branching. The branches are short and are developed generally in the middle of the ear. When the ear matures it curves in the form of a spoon. The awns remain straight but turn in parallel rows in the same direction as the convexity of the curved ear. The grains are smaller in size and white in colour instead of amber of the seeds of the untreated plants. These effects gradually disappear in the succeeding generation, and the plants are indistinguishable from those not treated with colchicine, (Fig. 1*b*).

Effects on ***Secale cereale,*** *Swat Rye.*

The plants raised from the treated and the untreated seeds are alike. There appears to be no difference between the two in the external morphological features of leaves, stem etc. The growth rate and the tillering capacity likewise remain unaffected. However, some major effects are noticeable in the ear. In the untreated plants the ears have, on the average, about 42 spikelets, but the ears of the treated plants bear, on the average, about 62 spikelets. These ears therefore appear to be abnormally long, and as such often droop down from the tip. Branching of the ear is quite common. The lower portion of the ear because of excessive branching appears bushy and generally 7-9 lower spikelets develop into shorter or longer branches, each developing 4-8 spikelets. In most of these branches seeds are not set, and therefore sterility is high in such ears. Further in some of the branched ears bulbils have also been developed. These vegetative buds develop in extreme cases to a length of about 3″-4″ with several leaves of about the same length. The leaves of these buds are very narrow and thick. Each vegetative shoot has an ear of its own but the ear does not develop normally. The rachis in the region of bulbils is

also abnormally elongated, and in rare cases the distance between two spikelets may be as much as one inch, when normally the spikelets are only 2/16"-3/16" apart. In one case the outer glume of the lowest spikelet was changed into a long leaflike structure, more or less of the same type as has been observed in strain 9D of *T. vulgare*, and reported earlier in this paper, (Fig. 2).

The bushy ears, and probably therefore the plants, remain green for a long time after the untreated plants have even been harvested. The seeds are slender and longer, and about 40% develop a blackish tinge in the pericarp, instead of the white-green of the seeds from the untreated plants. The subsequent behaviour of these seeds in the succeeding generations has not been studied yet.

GENERAL OBSERVATIONS

Although detailed conclusions must await the collection of more data and subsequent statistical analysis, yet a few general observations can be made at this stage, for they seem to be so obvious. The residual effects of colchicine seem to be quite variable, but it appears that the treatment has a definite effect on the tillering capacity, for in all the species of wheat the tillering is reduced to a smaller or a larger degree. The general dwarfing effect on *T. durum* may be due to a drastic disturbance in the physiology of growth, which undoubtedly also affects the development of tillers. These correlated developments along with similar effects on the ear and yield cannot be regarded as isolated variations. All of these are the result of the same change in the physiology of growth, rather adversely affected by the toxic doses of colchicine. These doses, which although were ineffective in producing polyploid conditions of the nucleus, yet were effective enough in initiating these temporary changes in plants. If these residual effects of colchicine can bring about appreciable and noticeable changes in plants without producing any change or changes in the chromosomes or their structure, then they appear to be helpful in an understanding of the physiological aspects of such phenomena as heterosis. Further by the use of proper growth substances and suitable treatments, it might also be possible to produce effects similar to heterosis. With such a tool in the hands of an agriculturist, higher crop yields could be obtained more easily, and also better controlled, without going through the arduous procedure of obtaining and maintaining the hybrid vigour.

SUMMARY

Seeds of *Triticum vulgare, T. durum, T. monococcum,* and *Secale cereale* were treated with colchicine, and such plants as did not show any doubl-

ing of chromosomes were selected for study of the residual effects of colchicine.

Several minor variations produced as a result of colchicine treatment have been described, but it is interesting to note that the same treatment also results in the production of branched and bushy ears.

It is suggested that since the residual effects of colchicine treatment produce appreciable variations in plants, it may be possible to initiate favourable effects by proper treatment with suitable growth substances.

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Meliola canarii Syd. on Bursera serrata Wall.

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In January 1952, a few leaves of *Bursera serrata* Wall., showing a thin film of superficial sooty fungal growth were collected by the second author from Baryadhola Forests, Chittagong Division, East Pakistan. The dark fungal growth was mainly present on the upper surface of the leaves, but a few spots were also observed on the under surface of some of the leaves. Microscopic examination revealed that the fungus belonged to the genus *Meliola*.

The literature on the subject shows that no species of *Meliola* has so far been recorded on this host. However, three species belonging to this genus have been recorded from two other plants of the family Burseraceae. These fungi are *M. amphitricha* Fr., and *M. evanida* Gaill on *Tetragastris balsamifera* Sw., and M. *canarii* Syd. on *Canarium villosum*.

The *Meliola* sp. on *B. serrata* Wall. differs from *M. amphitricha* Fr., and *M. evanida* Gaill, on account of its having two types of hyphopodia while the other two fungi possess only one type. However, Deighton considers it to be *M. canarii* as it matches with collections of this fungus on *Canarium* from the Philippines.

Thus it is not only a new host record but also the first record of *M. canarii* in the Indo-Pakistan sub-continent. A description is added below to facilitate its identification.

Colonies amphigenous, orbicular, becoming confluent and covering the greater part of the upper surface of the leaf (epiphyllous). *Mycelium* formed of dark brown, septate, branched, 7.6 μ thick hyphae. *Hyphopodia* of two types:capitate (alternate, the stalk cell shorter than the terminal one) and mucronate (generally opposite, septation doubtful), straight or slightly curved, measuring 22.8-26.6 x 7.6-11.4 μ, with an average of 24.9 x 10.5 μ and 11.4-22.8 x 3.8-11.4 μ, with an average of 19.5 x 9.5 μ respectively. *Mycelial setae* simple, straight or curved, dark brown, septate, surrounding the perithecia and measuring 101.5-928 x 5.7-9.5μ, with an average of 455.9 x 7.6 μ. *Perithecia* sub-globose, dark, measuring 101.5-203 x 97-188.5 μ, with

* Food and Agriculture Council, Pakistan, Karachi.
‡ Department of Plant Protection, Karachi.

an average of 155 x 145.3 μ. *Spores* 4-septate, dark brown to almost dark, oblong, with rounded ends and slightly constricted at the septa ; measuring 38-53.2 x 15.2-24.7 μ, with an average of 46.3 x 18.4 μ.

HABITAT : on leaves of *Bursera serrata* Wall.

LOCALITY : Baryadhola Forests, Chittagong Division, East Pakistan, 15.8.1952, leg. Azmatullah Khan.

SPECIMENS : At Central Mycological Herbarium, Department of Plant Protection Karachi (accession No. 2283) and at Herbarium Commonwealth Mycological Institute, Kew (accession No. Herb. IMI. 62667).

The assistance of Mr F.C. Deighton and the Director, Commonwealth Mycological Institute, Kew, England, in the identification of the fungus is gratefully acknowledged.

A new species of *Nitella* from West Pakistan

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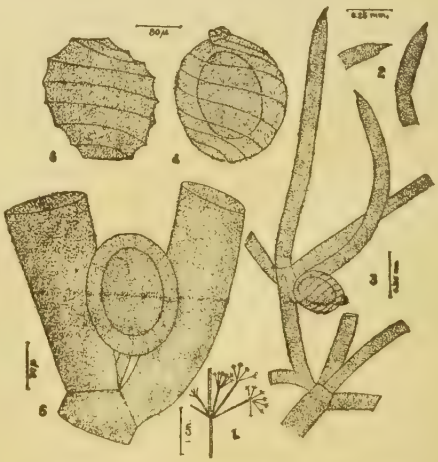
During 1952-53 three species of *Nitella* were collected from different parts of West Pakistan. Two of these have already been reported by the present author (Faridi, 1955). The third, with which the present paper is concerned, belongs to the group of dioecious polyarthodactylous Charales. It could not be identified with any species described by Kundu (1937) in his review of this group. It is closely related to *Nitella cristata* A. Br. and *N. struthioptila* Gr. & St., in the fruiting whorl forming dense heads and in having the ultimate cells of the dactyls acute and conical. However, it differs from the former in the absence of sterile branchlets and the presence of reticulate markings on the outer surface of the oospore, and from the latter in having solitary oogonia and in the oospores possessing prominent ridges. As the species differs from all other species of *Nitella* previously described, it has been designated as *Nitella pakistanica* sp. nov.

It does not appear to be common, having been collected only once.

Nitella pakistanica sp. nov.

Plantae dioeciae, 6-12 uncias altae; internodi longissimi, sextupli longitudinem ramulorum; caulis circa 275μ in diam.; ramuli 4-5, divaricati, uniseriati, bifurcati; nodi inflati, radiis primariis omnibus similibus, 1.4 mm longis, 111μ latis; digiti 4, longitudine inaequales, 2- vel rare 3-cellulati, cellula superiori parva, conica, circa 69μ longa, 28μ lata, cellula penultima ad apicem rotundata, 0.72-2.8 mm. longa, circa 97μ lata; verticilli fructiferi in planta femina in capita densiora quam in mascula; oogonia vel antheridia plerumque in quaque furca; oogonia solitaria, subglobosa, 260-300μ longa, 230-290μ lata, coronulam versus protracta; cellulae spirales 7-9-convolutae; coronula e cellulis 10 composita, circa 20μ alta, 37μ lata, persistens; oospora ovata, 180-265μ longa, 163-204μ lata, costis promi-



N. pakistanica. **1.** A portion of the entire plant. **2.** Apices of dactyls. **3.** Fruiting whorl (female). **4.** Oogonium. **5.** Fruiting whorl (male). **6.** An oospore.

nentibus 6-7 ornata, primum flava, in maturitate brunnescens ; membrana tenuis, flexibilis, brunnea, reticulata ; antheridia circa 184μ in diam.

In lacubus aquae dulcis, Lahore, 20. 2. 1953.

Dioecious. Plants 6 to 12 inches high ; internodes very long, about 6 times the length of the branchlets. Stem about 275μ in diameter. Branchlets 4 to 5, spreading, in one series ; twice furcate. Nodes swollen. Primary rays all similar, about 1.4 mm. long, 111μ broad. Dactyls 4, of unequal length ; 2-celled, rarely 3-celled, upper cell small, conical, about 69μ long, 28μ broad ; penultimate cell rounded at the apex, 0.72 to 2.8 mm. long, about 97μ broad. Fruiting whorls forming more dense heads in female plants than in the male. Oogonia or antheridia usually present at each forking. Oogonia solitary, globose, 260 to 300μ long, 230 to 290μ broad ; spiral cells with 7 to 9 convolutions ; coronula of 10 cells ; about 20μ high, 37μ broad, persistent. Oogonia prolonged towards the coronula. Oospore ovate, 180 to 265μ long, 163 to 204μ broad, with 6 to 7 prominent ridges ; yellow when young, brown at maturity ; outer membrane thin, flexible, brown, reticulate. Antheridium about 184μ in diameter. The male and female plants are similar.

A key to the species of *Nitella* described from West Pakistan is given below.

Branchlets in each whorl in one series

Monoecious.....*1. N. mucronata*

Dioecious.....*2. N. pakistanica*

Branchlets in each whorl in three series.....*3. N. hyalina*

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Studies on *Fimbriaria blumeana* Nees ab Esenbeck

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Fimbriaria blumeana is fairly common in Kagan Valley, Murree hills, Nathia Gali and Dunga Gali. It grows in patches of overlapping individuals in shady moist places at an altitude of 5000-7000 ft. The results of a detailed investigation of the material collected in July-September, 1955 are presented herewith.

The plant is monoecious. The antheridia are situated behind the stalk of the female receptacle. The archegonia are borne on a long-stalked female receptacle which is about 8-10 mm. long. The fully grown receptacle is usually 3-lobed and may have 3-5 involucres at maturity.

DEVELOPMENT OF THE ANTHERIDIUM : The antheridial initial divides by a transverse wall into an upper cell, the antheridium proper, and a lower stalk cell. More transverse divisions in the upper cell result in the formation of a short filament of four cells. Vertical walls then appear dividing the filament into quadrants. Further divisions of the cells are irregular, resulting in the formation of a multicellular antheridium. Periclinal walls are next laid down in these cells forming a layer of peripheral wall cells as distinguished from the inner spermatogenous tissue. The basal cell divides a few times by transverse and vertical walls forming a short stalk.

DEVELOPMENT OF THE ARCHEGONIUM : The archegonial initial divides by a transverse wall into an upper cell or archegonium proper and a lower cell forming the stalk. The upper cell divides by an oblique vertical wall into two cells. Two more walls are formed which are more or less at right angles to each other. The three walls thus formed differentiate the primary wall cells from the primary axial cell. The primary axial cell divides transversely into a small upper cover cell and a lower central cell. The central cell divides to form the primary neck canal cell and a primary ventral cell. The primary neck canal cell divides to form 6-8 neck canal cells. The primary ventral cell divides to form an upper ventral canal cell and a lower oosphere.

DEVELOPMENT OF SPOROGONIUM : The fertilized egg or oospore increases in size and develops a wall round it. It contains a dense protoplasm and a large nucleus. The wall of the venter now consists of 2-3 layers. The first division wall in the egg is horizontal, at right angles to the long axis of the archegonium. By this wall it is divided into two cells, an upper epibasal and a lower hypobasal. Each one of these cells again divides transversely by a wall, parallel to the first, so as to produce a four-celled filamentous embryo. After the formation of a row of four cells, vertical walls begin to form. These appear first in the apical and basal cells, later also in the middle cells. There is no regularity in the subsequent cell divisions and a multicellular embryo with more or less similar cells results. The formation of a two-sided apical cell was not seen by the writer. The vertical walls have no regularity at this stage. During further growth every segment divides rapidly by vertical as well as by transverse walls without any regular sequence. Consequently the embryo grows rapidly in length and comes to lie deep in the tissue of the receptacle. The cells divide with greater rapidity in the upper region than in the lower portion resulting in the appearance of a constriction in the middle. By the formation of periclinal walls in the peripheral cells, the capsule wall is differentiated from the inner sporogenous tissue. The lowermost layer of the embryo now forms the haustorium, which later on becomes bulbous. Shortly after this stage there is a differentiation of spore and elater mother cells. The elater mother cells become spindle shaped and undergo no reduction division They are transformed into elaters which are bispiral, 260μ in length and provided with 2 spiral thickenings.

INDEX

New genera and species are indicated in bold type.

Aecidium,
callianthum, 94
clematidis, 94
colchici, 94
crypticum, 94
euphorbiae, 95
hederae, 95
merenderae, 95
montanum, 95
orbiculare, 96
ranunculacearum, 96
Ahmad, S., 26
Akbar, Khursheed,
see Hafiz et al
Ansari, M. A. R., 102
Bibliography of flowering plants, 221
Boidin, J., 217
Bruelia
amsel, 135
antimarginalis, 140
daumae, 116
iliaci, 107
iliaci brevicolor, 110
iliaci indiensis, 111
ilmasae, 139
intermedia, 141
jacobi, 141
longifrons, 121
longifrons antiqua, 122
marginata, 132
merulensis, 119
myiophoneae, 124
oudhensis, 130
stresemanni, 112
turdinulae, 126
turdinulae eternitatus, 129
viscivori, 137
vulgata, 142
zootherae, 114
Bruelia spp.
studies on, 102
Buckleya, 183, 186
vitrinus, 187
Cerotelium, 29
fici, 29
Chrysomyxa, 29
deformans, 29
Cobboldostrongylus, 181, 187
axei, 188
Colchicine, residual effects of, 247
Coleosporium, 30
campanulae, 30
clematidis, 30
Colletotrichum capsici
on *Piper betle*, 216
Cronartium, 31
ribicola, 31
Diorchidium, 31
digitariae, 31
Endophyllum, 32
tuberculatum, 32
Faridi, M.A.F., 254
Fimbriaria blumeana
studies on, 256
Flowering plants, bibliography of, 221
Gilesia, 182, 184
longispicularis, 185
ovis, 186
Grosspiculagia, 178
trifida, 178
Gruhneria 176
bubalis, 177
Gymnosporangium, 32
clavariaeforme, 33
confusum, 32
distortum, 32
Hafiz, A. et al, 216, 252
Hussain, K. Z., 21
Hyalopsora, 33
polypodii, 33
Islam, A., 231
Khan, A. H., 1
Khan, Azmatullah
see Hafiz et al,
Khan, M. A., 256
Khan, Shams-ul-Islam, 247
Melampsora, 33
ciliata, 36
epitea, 35

Melampsora (continued)
euphorbiae, 33
euphorbiae-gerardianae, 34
larici-caprearum, 35
lini, 34
populnea, 35
salicis-albae, 35
Melampsoraceae, 28
Meliola canarii, 252
on *Bursera serrata*, 252
Monosporidium, 93
andrachnis, 93
Morphology of tail fin, 21
Nitella pakistanica, 254
Ophicephalidae,
morphology of tail fin, 21
Ostertagia, 159, 163
mossi, 167
muraschkinzevi, 165
ostertagi, 164
Peridermium, 93
indicum, 93
thomsoni, 93
Phakopsora, 36
zizyphi-vulgaris, 36
Phragmidium, 36
barclayi, 40
butleri, 36
kamtschatke, 37
mucronatum, 37
mysorense, 41
nepalensis, 39
papillatum, 39
potentillae, 40
rosae-moschatae, 37
shogranense, 41
tuberculatum, 39
Populus
Melampsora spp. on, 34
Potentilla
Phragmidium spp. on, 39
Probostrongylus, 188
hamatus, 189
probolurus, 189
Puccinia, 41
absinthii, 41
acetosae, 42
allii, 42
ambigua, 42
angelicae, 43
argentata, 43
aristidae, 43
barbeyi, 44
bithynica, 45
Puccinia (continued)
bullata, 45
butleri, 46
calcitrapae, 46
calthae, 47
carduorum, 46
caricis, 47
carthami, 47
chitralensis, 48
circaeae, 48
cirsii, 48
citrulli, 49
clavata, 49
collettiana, 50
coronata, 50
cynodontis, 50
duthiae, 51
echinopsis, 51
eremuri, 52
extensicola, 52
flavipes, 52
gentianae, 53
graminis, 53
helianthi, 54
heracleicola, 55
hieracii, 55,
holboelli, 55
hysterium, 56
invenusta, 56
iridis, 56
isiacae, 56
jorstadii, 57
junci, 57
komarovii, 58
kuehnii, 58
leveillii, 58
liberta, 59
ligustica, 59
longirostris, 59
major, 60
maydis, 60
melasmioides, 61
menthae, 61
nepalensis, 62
oenanthes, 62
philippinensis, 62
phlomidis, 63
phyllocladiae, 63
pimpinellae, 64
poae-nemoralis, 64
poarum, 64
polliniae, 65
polygoni-amphibii, 65
prenanthis var. *himalensis*, 66

Puccinia (continued)
propingua, 66
prostii, 66
pruni-spinosae, 67
pulsatillae, 68
pulvinata, 68
punctiformis, 68
purpurea, 69
pygmaea, 69
ranunculi-falcatae, 69
ribis, 69
romagnoliana, 70
rubigo-vera, 70
rufipes, 70
saxifragae-ciliatae, 71
schirajewskii, 72
scirpi, 72
silvatica, 73
solmsii, 73
sonchi, 73
striiformis, 73
swertiae, 74
tanaceti, 74
taraxaci, 74
tricholepidis, 75
triticina, 76
turgida, 76
tuyutensis, 77
umbilici, 77
urticae, 77
versicolor, 78
violae, 78
wattiana, 79
Pucciniaceae, 28
Pucciniastrum, 79
agrimoniae, 79
areolatum, 79
Pucciniostele, 79
clarkiana, 80
Ravenelia, 80
mimosae-himalayae, 80
sessilis, 81
taslimii, 81
Residual effects of Colchicine, 247
Rosa
Phragmidium spp. on, 36
Rosellinia necatrix
Growth and nutritional requirements of, 1
Rubus
Phragmidium spp. on, 40
Salix
Melampsora spp. on, 34
Sarwar, M. M., 145
Shariff, Murtaza
see Hafiz et al
Sjobergia, 173
lyrata, 174
nemorhoedi, 175
Skeleton of *Uromastix hardwickii*, 231
Stadelmannia, 168
circumcincta, 168
pinnata, 171
trifurcata, 171
turkestanica, 170
Stereum ahmadi, 217
Stewart, R. R., 221
Tail fin of Ophicephalidae, 21
Thrushes,
Bruelia spp. on, 102
Trachyspora, 82
alchemillae, 82
Trichostrongylids of ruminants, 145
Trichostrongylus, 180, 183
retortaeformis, 184
Uredinales, 27
Uredinales of West Pakistan, 26
Uredo, 92
dalbergiae, 92
otostegiae, 92
ravennae, 93
rottboelliae, 93
vicatiae, 93
Uromastix hardwickii,
Postcranial skeleton of, 231
Uromyces, 82
andropogonis-annulati, 82
anthyllidis, 83
apludae, 82
appendiculatus, 82
capitatus, 83
chenopodii, 83
ciceris-arietini, 83
decoratus, 84
eragrostidis, 84
fabae, 84
fritillariae, 85
geranii, 85
heteromallus, 85
ignobilis, 85
kondoi, 86
lapponicus, 86
lespedezae-sericeae, 86
lineolatus, 87
lycoctoni, 87
minor, 87
nerviphilus, 88

Uromyces (continued)
orientale, 88
phacae-frigidae, 88
polygoni-avicullariae, 88
proeminens, 89
punctatus, 89
rumicis, 89
setariae-italicae, 89
striatus, 90
striolatus, 90
superfluus, 90
thallungi, 90
trifolii, 91
trifolii-repentis, 91
tuberculatus, 91
valerianae-wallichii, 92

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